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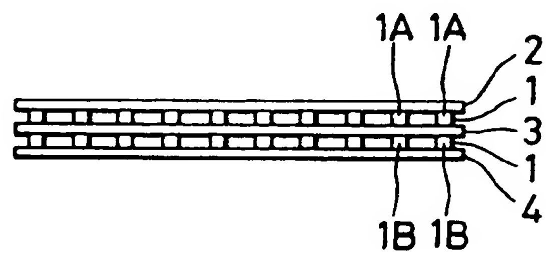
(54) Pressure sensor

(57) A pressure sensor which comprises a pair of electrode layers and a dielectric layer composed of a rubber elastic body positioned between the pair of electrode layers and also functioning as a spacer for the electrodes, the rubber elastic body being capable of elastically deformed to undergo change in electrostatic capacity upon being pressed, and said change in electrostatic capacity being utilized to measure the pressure applied thereto.

Fig1

(b)



Description

Field of the Invention

This invention relates to a pressure sensor which contains a dielectric layer comprising a rubber elastic body, said rubber elastic body being capable of elastically deformed to undergo change in electrostatic capacity upon being pressed, and said change in electrostatic capacity being utilized to measure the pressure applied thereto. More particularly, it relates to a pressure sensor which enables one to measure weight or pressure with high accuracy without employing any complicated structure.

Prior Art

As pressure sensors for detecting pressure, there have conventionally been known those which utilizes a load cell. The load cell-using pressure sensors are generally grouped into two types: one being a type wherein a strain gauge is pasted to an elastic body to constitute a pressure sensor and which utilizes change in electrical resistance.

In addition, a rubber mat type which can also be used as a pressure sensor has been made practical which employs a complicated structure utilizing dielectric properties of an elastic rubber body and which utilizes change in electrostatic capacity with relieving hysteresis essential to elastic rubber body to be generated when pressure is applied to or removed from the eleastic body. (See, Japanese Examined Patent Publication No. 50-19057.)

Further, there has been proposed a pressure sensor device in which hysteresis essential to rubber is relieved with the aid of a completely elastic body such as a metal spring, and a rubber with a high dielectric constant is employed to enhance pressure sensitivity, said completely elastic body such as metal spring also serving to improve reproducibility owing to its restoring force. (See, Japanese Examined Utility Model Publication No.H 5-35303.)

Subjects that the invention is to solve

However, pressure sensors using a load cell have the problems that both of the load cell-using types require a complicated structure and that, since steel-made springs are mainly used as the elastic bodies, they are too heavy, thick, and expensive, and are liable to suffer deterioration in precision upon being shocked, for example, upon being dropped.

Rubber mat-type pressure sensors described hereinbefore have the problem that, since they utilize simple compression deformation of rubber elastic body, they are seriously affected by the hysteresis essential to the elastic rubber body unless a special mechanism for relieving the hysteresis is employed. Therefore, they generate, as produced, inconsistent outputs due to lot-to-lot variation, and must be checked one by one to adjust or correct the output by electrical treatment, thus their production requiring complicated works.

In addition, with the aforesaid rubber mat type ones, defomation amount upon being pressed is comparatively small in comparison with other type ones. Hence, only a small output is obtained per unit area and, in order to obtain a larger amount of variation of capacitance as a condenser, a large amount of mat area is necessary, thus downsizing of the pressure sensors to the size of load cell type ones having been difficult.

Further, the pressure sensor devices using a rubber elastic body with a high dielectric constant have the problem that, since the dielectric layer comprising a rubber elastic body is formed by adding a large amount of a component having a high dielectric constant such as barium titanate to a non-polar rubber (300 to 800 parts by weigh per 100 parts by weight of non-polar rubber) for enhancing the dielectric constant of the layer, it shows such a large hysteresis as well as a high dielectric constant that a completely elastic body such as a metal spring must be used in combination to relieve the hysteresis so as to assure restoring properties and sufficient precision even after repeated uses, thus a complicated structure being required.

Heretofore, as is shown in Fig. 39, the dielectric layer 7' has a rectangular section taken along the longitudinal direction (crossing at right angles to the electrode layer surface), and is deformed only in the simple compression direction (vertical direction in Fig. 39). Thus, as is shown in Fig. 40, though capacitance of the dielectric layer 7' changes in a linear manner in the initial deformation area A, the capacitance does not change in a linear manner in the region B passing point P where the capacitance is required to change in a linear manner. Additionally, in Fig. 39, numerals 6' and 8' represent a first electrode layer and a second electrode layer, respectively.

It may be considered to decrease the ratio of width W to thickness T of the dielectric layer 7' shown in Fig. 39 so as to increase the amount of variation of capacitance upon the same load being applied. In such case, however, deformation behaviour of the dielectric layer 7' becomes so unstable that there arises the problem that the first electrode layer 6' and the second electrode layer 8' shift in the right or left direction in Fig. 39.

In addition, the rubber constituting the dielectric layer is a viscoelastic material, and hence it shows hysteresis. The pressure sensor must use a completely elastic body other than rubber, such as a metal spring, as an aid to keep

enough precision as a pressure sensor, thus the pressure sensor being required to have a complicated structure.

Object of the Invention

An object of the present invention is to provide a pressure sensor which enables one to measure pressure or weight with a high accuracy without requiring any complicated structure.

Means to solve the Subject

This invention is proposed to attain the above-described object. According to one embodiment of the invention, the present invention includes the following features.

That is, according to the present invention, there is provided a pressure sensor which comprises a pair of electrode layers and a dielectric layer composed of a rubber elastic body positioned between the pair of electrode layers and also functioning as a spacer for the electrodes, said dielectric layer showing a tan δ at 1 to 30 Hz at a temperature of 10 to 30°C of 0.03 or less and having a rubber hardness of 20 to 80 degrees in terms of scale A according to JIS-K-6301 at 10 to 30 °C.

Further, according to the present invention, there is provided the pressure sensor as described in claim 1, which has an impact resilience of 75 % or more measured according to JIS-K-6301 at 10 to 30°C.

Still further, according to the present invention, there is provided the pressure sensor as described in claim 1 or 2, which has a compression set of 3 % or less measured according to JIS-K-6301 at 10 to 30°C.

Still further, according to the present invention, there is provided the pressure sensor as described in one of claims 1 to 3, wherein said dielectric layer is formed by one of natural rubber, polybutadiene rubber, polyisoprene rubber, polyurethane rubber and silicone rubber.

According to another embodiment of the invention, the present invention includes the following features.

That is, according to the present invention, there is provided a pressure sensor which comprises a first electrode layer and a second electrode layer positioned parallel to each other and a dielectric layer made of rubber elastic body in a continuous length spacing the two electrode layers from each other with one surface thereof being in a close contact with the first electrode layer and the other opposite surface thereof being in a close contact with the second electrode layer, with said dielectric layer being formed so that one of the contact surface is shifted from the other opposite contact surface when viewed in the direction crossing at right angles to the electrode layer.

Still further, according to the present invention, there is provided a pressure sensor as described in claim 5, wherein said dielectric layer has an almost parallelogramic section taken along the plane crossing at right angles to the longitudinal direction of the dielectric layer.

Still further, according to the present invention, there is provided a pressure sensor as described in claim 6, wherein a plane crossing at right angles to the first and the second electrode layers crosses at an angle of 30 to 85 degrees to said dielectric layer.

Still further, according to the present invention, there is provided a pressure sensor as described in claim 5 or 6, wherein one side plane of the dielectric layer crosses at an angle of 30 to 85 degrees to said second electrode layer, and the other opposite side plane of the dielectric layer crosses at an angle of 90 to 145 degrees to said second electrode layer.

Still further, according to the present invention, there is provided a pressure sensor as described in one of claims 5 to 8, wherein said dielectric layer comprises a first dielectric layer piece and a second dielectric layer piece disposed so that, when pressure is applied to the sensor in the vertical direction with respect to the surfaces of said first and second electrode layers, forces of shifting respective said electrode layers are cancelled out.

Still further, according to the present invention, there is provided a pressure sensor as described in claim 9, wherein number of said first dielectric layer piece(s) is almost the same as number of said second dielectric layer piece(s).

Still further, according to the present invention, there is provided a pressure sensor as described in one of claims 5 to 10, wherein a quotient obtained by dividing the length of said contact surface in the direction crossing at right angles to the longitudinal direction of said dielectric layer by the distance between the first and the second electrode layers is 0.2 to 5.0.

Still further, according to the present invention, there is provided a pressure sensor as described in one of claims 5 to 11, wherein said dielectric layer has a rubber hardness of 20 to 80 degrees measured in terms of scale A according to JIS-K-6301.

Still further, according to the present invention, there is provided a pressure sensor as described in one of claims 5 to 12, wherein distance between said first electrode layer and said second electrode layer is 0.2 to 5.0 mm.

Still further, according to the present invention, there is provided a pressure sensor as described in one of claims 5 to 13, wherein three or more odd-number electrode layers are provided, with said dielectric layer being closely disposed between each pair of the electrode layers.

Embodiment of the Invention

It is well known that rubber elastic bodies show both elastic behavior and viscous behavior, thus being also called visco-elastic bodies. When repeated compression stress and tensile stress are applied from outside to a rubber elastic body, there arises a time lag between stress and displacement, thus causing so-called visco-elastic behavior which generates a stress relaxation such as hysteresis or creep. However, if the viscous behavior essential to a rubber elastic body is minimized, even a rubber elastic body can be used as a spring showing almost no viscous behavior like a metal spring.

Hysteresis or stress relaxation of a rubber elastic body becomes smaller as tan , which is one parameter for confirming visco-elastic behavior, becomes closer to zero, whereas it becomes larger as tan becomes larger. In addition, hysteresis or stress relxation becomes more reduced as compression set becomes closer to zero, but becomes more serious as compression set becomes larger. As is well known, thermoplastic elastic polymers generally have a small tan δ, thus being good elastomers with a good rubber elasticity, but many of them show a large compression set and disadvantageous hysteresis or stress relaxation. In order to attain the same spring behavior as a metal spring, it is the most important for the polymer to show a high impact resilience measured according to JIS-K6301, a small tan δ, and a small compression permanent strain.

With the above-described points in mind, the inventors have made investigations to minimize the viscous behabior by selecting a proper polymer and designing a proper rubber composition taking molecular structure of rubber elastic body into consideration and, as a resulut, have develpped a rubber elastic body having the physical properties described in claims 1 to 3 and have confirmed that the rubber elastic body shows such a minimized viscous behavior that it can be used for a pressure sensor.

As a result of investigations checking the performance as a pressure sensor of rubber elastic bodies by changing composition formulations taking well-known molecular structure into consideration, it has been found that natural rubber, polyisoprene rubber, polybutadiene rubber, and silicone rubber are suited, thus determining rubber materials described in claim 4 as rubber elastic body materials enabling one to attain the physical properties described in claims 1 to 3 by properly selecting composition formulation or the like. Of these rubbers, silicone rubber is one of the optimal rubbers, since it undergoes only a small change in spring constant from a lower temperature zone to a higher temperature zone or with time, and shows a higher rubber elasticity than other elastic body materials, a small tan and a small compression set. Hence, a pressure sensor produced using polyurethane rubber has a higher sensitivity than that produced by using other material, thus polyurethane rubber being one of effective materials for the pressure sensor.

In connection with the invention described in claim 1, hysteresis of the pressure sensor is liable to become large when tan exceeds 0.03 or when rubber hardness in terms of scale A measured according to JIS-K-6301 is outside the range of from 20 to 80 degrees.

In connection with the invention described in claim 2, compression set is liable to become large when impact resilience measured according to JIS-K-6301 at 10 to 30°C is less than 75 %.

Further, in connection with the invention described in claim 3, hysteresis of a pressure sensor is liable to become large when compression set measured according to JIS-K-6301 at 10 to 30°C is larger than 3 %.

The pressure sensor described in claim 5 comprises a first electrode layer and a second electrode layer disposed parallel to each other and a dielectric layer between the two layers. The dielectric layer is formed in a continuous length and is composed of a rubber elastic body, and functions to space the two electrode layers from each other, with one surface being in a close contact with the first electrode layer and the other opposite surface in a close contact with the second electrode layer. In the invention described in claim 5, the dielectric layer is formed so that one of the contact surface is shifted from the other opposite contact surface when viewed in the direction crossing at right angles to the electrode layer.

The pressure sensor in accordance with the present invention does not require an aid of a completely elastic body such as a metal spring, that is, it enables measurement with a high accuracy in spite of its simple structure.

In the invention described in claim 5, the dielectric layer undergoes shearing deformation when a load is applied thereto in the direction crossing at right angles to each surface of the first and the second electrode layers across which a voltage is applied, thus enough deformation amount being assured. Therefore, a region is broadened wherein capacitance changes in a linear manner as the first electrode layer and the second electrode layer migrate nearer to, or far from, each other, thus detection sensitivity being improved.

Additionally, in the present invention, the phrase "one of the contact surface between one surface of the dielectric layer and the first electrode layer is shifted from the other opposite contact surface between the other opposte surface of the dielectric layer and the second electrode layer" includes the case wherein, as shown in Fig. 22, one side 50A of the contact surface 50 is shifted from one side 52A of the contact surface 52, and another side 50B of the contact surface 50 is shifted from another side 52B of the contact surface 52 in the horizontal direction in Fig. 22, and also includes the case shown in Fig. 26(A).

That is, in Fig. 26(A), one side 41E of the contact surface 41A is almost at the same position as one side 41F of

the contact surface 41B in the horizontal direction in Fig. 26, and only another side 41C of the contact surface 41A is shifted from another side 41D of the contact surface 41B in the horizontal direction in Fig. 26.

Additionally, in Fig. 22, numeral 53 designates a first electrode layer, 54 a second electrode layer, 9' a first dielectric body piece, and 10' a second dielectric body piece. In Fig. 26(A), numeral 39 designates a first electrode layer, 40 a second electrode layer, 41 a first dielectric body piece, and 42 a second dielectric body piece. Additionally, the first dielectric body piece 9' and the second dielectric body piece 10' are disposed so that they are in a horizontally symmetrical position with respect to sectional shape. Similarly, the first dielectric body piece 41 and the second dielectric body piece 42 are disposed so that they are in a horizontally symmetrical position with respect to sectional shape.

The pressure sensor described in claim 6 has a dielectric layer having a sectional shape of almost parallelogram taken along the plane crossing at right angles to the longitudinal direction of the dielectric layer. Since the dielectric layer is formed in a shape of shearing deformation, the range wherein capacitance changes in a linear manner can be broadened due to the same reason as with claim 1, thus detection sensitivity being improved.

The pressure sensor described in claim 7 is constituted so that a plane crossing at right angles to the first and the second electrode layers crosses at an angle of 30 to 85 deg., preferably 45 deg., to the dielectric body layer. A sufficient shearing deformation amount of the dielectric layer is assured owing to the above-described structure. It is possible to change the angle to 90 degrees or to about 0 degree at which the electrode layers and the dielectric layer are in an almost parallel position to each other. However, if the angle exceeds 85 degrees, a ratio of the compresion deformation tends to increase whereas a ratio of the shearing deformation tends to decrease. On the contrary, if the angle is less than 30 degrees, the ratio of compression deformation tends to decrease whereas the ratio of shearing deformation tends to increase, thus adhesion breakage with the electrode layer possibly taking place.

The pressure sensor described in claim 8 is constituted so that one side plane of the dielectric layer crossing both the first and the second electrode layer crosses at an angle of 30 to 85 degrees to said second electrode layer, and the other opposte side plane of the dielectric layer crosses at an angle of 90 to 145 degrees to the second electrode layer. A sufficient shearing deformation amount of the dielectric body layer is assured owing to the above-described structure. If the former and the latter angles are outside the above-described ranges, that is, if the angles exceed the above-described ranges, a ratio of compression defmation tends to increase whereas a ratio of shearing deformation tends to decrease and, if the angles are smaller than the lower limits, an adhesion breakage tends to take place.

In the pressure sensor described in claim 9, the dielectric layer comprises a first dielectric layer piece and a second dielectric layer piece disposed so that, when pressure is applied to the sensor in the vertical direction with respect to the surfaces of said first and second electrode layers, forces of shifting respective electrode layers are cancelled out.

The above-described structure of the pressure sensor described in claim 9 serves to prevent the first and the second electrode layer from shifting in a direction different from the pressure-applying direction upon the dielectric layer being deformed.

The pressure sensor described in claim 10 is constituted so that number of the first dielectric layer piece(s) is almost the same as number of the second dielectric layer piece(s). Since the effect of preventing the first electrode layer from shifting in a direction different from the pressure-applying direction and the effect of preventing the second electrode layer from shifting in a direction different from the pressure-applying direction are almost the same, the two electrode layers are prevented from shifting.

In addition, in the pressure sensor described in claim 11, a quotient obtained by dividing the length of the contact surface in the direction crossing at right angles to the longitudinal direction of the dielectric layer by the distance between the first and the secon electrode layers is 0.2 to 5.0. This serves to facilitate production of the pressure sensors and minimize differences between produced pressure sensors.

If the quotient is less than 0.2, production of the pressure sensor tends to become difficult whereas, if more than 5.0, a ratio of compression deformation tends to increase, with a ratio of shearing deformation decreasing.

In the pressure sensor described in claim 9, the dielectric layer has a rubber hardness of 20 to 80 degrees measured in terms of scale A according to JIS-K-6301, whereby various general-purpose pressure sensors of from a pressure sensor whose maximum measurable weight is about 10 kg to a pressure sensor whose maximum measurable weight is 1000 kg can be manufactured.

In the invention described in claim 13, distance between the first electrode layer and the second electrode layer is 0.2 to 5.0 mm, which serves to facilitate production of the pressure sensors with less differences therebetween.

In the invention described in claim 14, three or more odd-number electrode layers are provided, with said dielectric layer being closely disposed between each pair of the electrode layers. Accordingly, in this invention, sufficient sensitivity can be obtained without any damage of the pressure sensor, even when the dielectric layer is deformed too much due to too much load applied thereto to a degree out of the region where the dielectric layer is deformed in a linear manner, or even when the dielectric layer is similarly deformed too much to possibly be damaged.

Brief Description of the Drawings

Fig. 1(a) is a perspective view of a dielectric layer.

Fig. 1(b) is a sectional view of a pressure sensor wherein dielectric layer pieces disposed as an upper layer and a lower layer are parallel to each other.

Fig. 1(c) is a perspective view of electrode layers.

Fig. 2 is a perspective view showing the state of measuring capacitance of a pressure sensor.

Fig. 3(a) is an analyzed perspective view of a pressure sensor.

Fig. 2(b) is a perspective view of a pressure sensor.

Fig. 4 is a perspective view showing the state of measuring capacitance of a pressure sensor.

Fig. 5 is a graph showing the relation between load applied to the pressure sensor of Example 1 and change in capacitance.

Fig. 6 is a graph showing the relation between load applied to the pressure sensor of Example 2 and change in capacitance.

Fig. 7 is a graph showing the relation between load applied to the pressure sensor of Example 3 and change in capacitance.

Fig. 8 is a graph showing the relation between load applied to the pressure sensor of Comparative Example 1 and change in capacitance.

Fig. 9 is a graph showing the relation between load applied to the pressure sensor of Comparative Example 2 and change in capacitance.

Fig. 10 is a graph showing the relation between load applied to the pressure sensor of Example 1 and change in capacitance.

Fig. 11 is a graph showing the relation between load applied to the pressure sensor of Example 2 and change in capacitance.

Fig. 12 is a graph showing the relation between load applied to the pressure sensor of Example 3 and change in capacitance.

Fig. 13 is a graph showing the relation between load applied to the pressure sensor of Comparative Example 1 and change in capacitance.

Fig. 14 is a graph showing the relation between load applied to the pressure sensor of Comparative Example 2 and change in capacitance.

Fig. 15 is a graph showing the relation between load applied to the pressure sensor of Example 4 and change in capacitance.

Fig. 16 is a graph showing the relation between load applied to the pressure sensor of Comparative Example 3 and change in capacitance.

Fig. 17 is a graph showing the relation between load applied to the pressure sensor of Comparative Example 4 and change in capacitance.

Fig. 18 is a graph showing the relation between load applied to the pressure sensor of Comparative Example 5 and change in capacitance.

Fig. 19 is a graph showing the relation between load applied to the pressure sensor of Example 5 and change in capacitance.

Fig. 20 is a graph showing the relation between load applied to the pressure sensor of Comparative Example 6 and change in capacitance.

Fig. 21 is a graph showing the relation between load applied to the pressure sensor of Comparative Example 7 and change in capacitance.

Fig. 22 is a sectional view showing one specific example of a second embodiment of the present invention.

Fig. 23 is a sectional view showing another specific example of the second embodiment of the present invention.

Fig. 24(A) is a side view of a pressure sensor.

Fig. 24(B) is a perspective view of a pressure sensor wherein the upper dielectric pieces are disposed at right angles to the lower dielectric pieces.

Fig. 24(C) is a perspective view of electrode layers.

Fig. 24(D) isa perspective view of dielectric pieces.

Fig. 25(A) to (E) are sectional views of pressure sensors.

Fig. 26(A) to (D) are sectional views of pressure sensors.

Fig. 27(A) to (E) are sectional views of pressure sensors.

Fig. 28 is a perspective view showing the state of measuring capacitance of a pressure sensor.

Fig. 29 is a graph showing the relation between load and capacitance.

Fig. 30(A) is a plan view of a pressure sensor before a first electrode is applied thereto.

Fig. 30(B) is a side view of (A).

Fig. 30(C) is a sectional view of a pressure sensor after the first electrode layer is applied thereto.

Fig. 31 is a graph showing the relation between load and capacitance.

Fig. 32 is a plan view of a pressure sensor before a first electrode is applied thereto.

Fig. 33 is a side view of Fig. 32.

Fig. 34 is a plan view of a pressure sensor before a first electrode is applied thereto.

Fig. 35 is a side view of Fig. 34.

Fig. 36 is a plan view of a pressure sensor before a first electrode is applied thereto.

Fig. 37 is a view of the pressure sensor of Fig. 36 viewed from one longitudinal direction of the dielectric layer.

Fig. 38 is a view of the pressure sensor of Fig. 36 viewed from the other longitudinal direction of the dielectric layer.

Fig. 39 is a sectional view of a conventional pressure sensor.

Fig. 40 is a graph showingthe relation between load and change in capacitance with respect to a conventional pressure sensor.

Detailed Description of Preferred Embodiments

One embodiment of the present invention is described in more detail by reference to Examples.

Examples 1 to 3 and Comparative Examples 1 and 2

In order to confirm the relationship between tan δ or compression set and hysteresis, raw rubber samples were prepared by using polybutadiene rubbber as a rubber material, compounding various components to attain a rubber hardness after vulcanization of 40 degrees measured in terms of scale A according to JIS-K-6301, and kneading the resulting composition in a roll for kneading rubber. Each raw rubber sample was press molded by electrical heating under the conditions of 165 °C x 15 minutes and 200 kg/cm^2 to prepare vulcanized rubber sheet samples of 1.5 mm in thickness, 150 mm in width, and 200 mm in length.

Compounding formulations for the raw rubber materials used in Examples 1 to 3 and Comparative Examples 1 and 2 are as shown in Table 1.

Observed values of rubber hardness of the vulcanized rubber sheet samples obtained in Examples 1 to 3 and Comparative Examples 1 and 2, measured in terms of scale A at 25°C according to JIS-K-6301, tan δ values at 10 Hz measured at 25°C by an automatic dynamic visco-elasticity-measuring apparatus, DDV-25FP, made by ORIENTEC, and compression set values measured at 25°C according to JIS-K-6301 are tabulated in the lower part of Table 1.

Then, each of the vulcanized sheet samples was cut into strip pieces of 1.5 mm in thickness, 1.5 mm in width, and 200 mm in length as shown in Fig. 1(a). The thus cut 20 strip pieces were adhesively placed between a first electrode layer 2, a second electrode layer 3, and a third electrode layer 4 shown in Fig. 1(C) using an urethane series two-part adhesive to prepare test samples of Examples 1 to 3 and Comparative Examples 1 and 2 as shown in Fig. 1(b). In each test sample, dielectric pieces 1A constituting the upper dielectric layer 1 and dielectric pieces 1B constituting the lower dielectric layer are parallel to each other as shown in Fig. 1(b).

Additionally, as the electrode layers, aluminum-made planar plates of 200 mm in width, 250 mm in length, and 5 mm in thickness were used.

Each test sample was connected to a precision LCR meter, HP4284, made by Huret paccard Co. in such manner that, as is shown in Fig. 2, the first electrode layer 2 and the second electrode layer 4 were connected to one output terminal 9 of the precision LCR meter via a connecting portion 8 using wire cords 6 and 7, and the remaining second electrode 3 was connected to the other output terminal 11 of the LCR meter through a wire cord 10, and an alternating current voltage of 1 MHz 6 V was applied thereacross to measure capacitance.

Then, a 20-kg weight or weights 12 were placed in piles on each of the thus connected test samples in number of one, two, three, four,and five to apply loads of 20 kg, 40 kg, 60 kg, 80 kg, and 100 kg, respectively. Capacitance of each test sample under each load was measured 7 times. Maximum and minimum values for each load were plotted to obtain graphs shown in Figs. 5 to 9. In the Figures, (a) is a curve obtained by plotting maximum values of capacitance, (b) a curve obtained by plotting minimum values.

Additionally, Fig. 5 is a graph showing the results of the measurement in Example 1, Fig. 6 a graph for Example 2, Fig. 7 a graph for Example 3, Fig.8 a graph for Comparative Example 1, and Fig. 9 a graph for Comparative Example 2.

What is important as a pressure sensor is to produce outputs with a good reproducibility with extremely small scattering. It is proved, by comparing the difference between the maximum value and the minimum value for a load of 100 kg shown in Figs. 5 to 9, that test samples showing smaller tan tend to show smaller difference between the maximum values and the minimum values and, theerefore, smaller hysteresis.

That is, the difference between the maximum value and the minimum value with the test sample of Example 1 (tan δ = 0.01) is 1 PF, whereas that with the test sample of Comparative Example 2 (tan δ = 0.043) is 8 PF.

Therefore, assuming manufacture of pressure sensors allowing to measure a weight of up to 100 kg for measuring

pressure of pressure rubber rolls of a printing press, the test sample in Example 1 enables one to manufacture a pressure sensor which shows a change in capacitance of 0.68 PF per kg since its capacitance changes from 0 to 68 PF when weights were placed thereon in piles up to 100 kg. Thus, in the case of measuring a weight of 100 kg using this pressure sensor, scattering width is as small as about 1.5 kg due to the difference between the maximum value and the minimum value being only 1 PF, which means that pressure change can be read by at least 2 kg unit. In addition, a pressure sensor capable of measuring the maximum weight of 100 kg with a minimum reading unit of 2 kg, which has a light weight and a simple structure composed of a dielectric layer rubber and electrode plates and yet is difficult to break, can be manufactured at a low cost.

On the other hand, in the case of manufacturing a pressure sensor capable of measuring the weight of 100 kg using the test sample of Comparative Example 2, there is manufactured a pressure sensor which shows a change in capacitance of 0.48 PF per kg since its capacitance changes changes from 0 to 48 PF when weights were placed thereon in piles up to 100 kg. Thus, in the case of measuring a weight of 100 kg using this pressure sensor, scattering width is as large as about 16.6 kg due to the diffrence between the maximum value and the minimum value for 100 kg being 8 PF, which means that pressure change can be read with a poor precision only by 15 kg to 20 kg unit at the least. Accordingly, only the test samples of Examples 1 to 3 can provide pressure sensors with little scattering, and a suitable tan can be concluded to be 0.03 or less for this reason.

In addition, as is well known, there are no relations between tan δ and compression set with respect to thermoplastic elastic bodies. In the case of vulcanized rubber elastic bodies having a cross-linked structure, however, there is a close relation between tan δ and compression set properties. That is, the smaller the tan δ, the smaller the compression set, with smaller compression set being preferred.

With respect to impact resilience, it is closely related to tan δ with both the thermoplastic elastic bodies and the vulcanized rubber elastic bodies having a cross-linked structure. That is, the smaller the tan δ, the larger the impact resilience, with larger impact resilience being preferred. With the vulcanized rubber elastic bodies having a cross-linked structure, however, impact resilience is in cose relation with to compression set as is well known and, a material having a larger impact resilience shows a smaller compression set, thus being preferred.

It has been concluded, based on the thus obtained results with the above-described facts in mind, that compression set as one parameter of rubber elastic body for obtaining good pressure sensors be most preferably 3 % or less, and impact resilience be brought near to 100 % as much as possible, with an impact resilience of 75 % or more being most preferred.

Then, relation between tan δ or compression set and hysteresis was examined by continuously conducting application and removal of pressure.

In this examination, the aforesaid test samples of Examples 1 to 3 and Comparative Examples 1 and 2 were again used. The same tests as described hereinbefore were conducted using the same testing apparatus. That is, after measuring capacitance for 0 kg without the weight, pressure was applied thereto in a continuous manner of 20 kg, 40 kg, 60 kg, 80 kg, and 100 kg using the same weights. Then, weights were continuously removed one by one to apply weight of 80 kg, 60 kg,40 kg, 20 kg, and 0 kg to measure capacitance to obtain graphs shown by Figs. 10 to 14. Additionally, Fig. 10 shows the results of the measurement in Example 1, Fig. 11 in Example 2, Fig. 12 in Example 3, Fig. 13 in Comparative Example 1, and Fig. 14 in Comparative Example 2.

It can be seen, from Figs. 10 to 14, that the test sample of Example 1 showed the least hysteresis, whereas the test sample of Comparative Example 2 showed the largest hysteresis, and that a larger tan gave a larger hysteresis.

Additionally, the test samples of Examples 1 to 3 were found to show similar tendency in various pressure-applying tests, and it was found that the best results were obtaned when pressure sensors had a tan of 0.02 or less, a compression set of 3 % or less, and an impact resilience of 75 % or more.

Table 1

Formulation		Example 1	Example 2	Example 3	Comparative Ex. 1	Comparative Ex. 2
1	JSR BR-01	100	←	←	←	←
2	Active Zinc Flower	5.0	←	←	←	←
3	Stearic Acid	0.5	←	←	←	←
4	Antioxidant 3C	0.5	←	←	←	←
5	Di-cup-40-C	6.0	←	←	←	←
6	Diana PX-90	8	14	25	32	39

Table 1 (continued)

Formulation		Example 1	Example 2	Example 3	Comparative Ex. 1	Comparative Ex. 2
7	Nipsil VN3	2	6	13	24	37
8	Precipitated Sulfur	1.0	←	←	←	←
Physical Properties of Vulcanized Rubber	*1	40	40	40	40	
	*2	0.010	0.018	0.025	0.037	0.043
	*3	86 %	78 %	72 %	68 %	63 %
	*4	1.0 %	2.6 %	3.4 %	5.8 %	6.8 %

*1: Hardness (degree)
*2: tan δ
*3: Impact resilience
*4: Compression set

Example 4 and Comparative Examples 3 to 5

Then, tan δ, impact resilience, permanent set, and hysteresis were measured using commercially available silicone rubbers of grades of 50 degrees in rubber hardness having different physical properties. As is shown in Table 2, compounding procedures were conducted according to the formulations specified by the manufacturers, and each of the resulting compounds was kneaded, and was subjected to press molding by applying electrical heating at 170°C for 10 minutes under a pressure of 200 kg/cm^2 to prepare a vulcanized rubber sheet of 1.5 mm in thickness, 100 mm in width, and 200 mm in length, followed by additional vulcanization at 200°C for 4 hours in an electric furnace. Then, tan δ of each sample sheet was measured.

Impact resilience and compression set were measured using the samples molded under the same conditions as described above respectively in exclusive molds. Results thus obtained were as shown in Table 2. Then, each of vulcanized rubber sheet samples obtained in Example 4 and Comparative Examples 3 to 5 was cut into strip pieces of 1.5 mm in thickness, 3 mm in width, and 50 mm in length having a rectangular section as shown in Fig. 3(a), numeral 12 (first dielectric layer) and 13, a set of 10 pieces were adhered to the first electrode layer 14 and the second electrode layer 15 with an adhesive to form an upper dielectric layer, and another set of 10 pieces to the second electrode layer 15 and the third electrode layer 16 with the adhesive to form a lower dielectric layer, with the strip pieces of the upper layer crossing the strip pieces of the lower layer at an angle of 90 degrees. Thus, there were prepared test samples for Example 4 and Compraative Examples 3 to 5. [Fig. 3(b)] Additionally, as the electrode layers for the respective samples, aluminum plates of 50 x 50 mm and 1.0 mm in thickness were used and, as the adhesive, an RTV series adhesive of 30 degrees in hardness was used.

Then, rubber plates 19 and 20 were respectively adhered to the first electrode layer 14 and the third electrode layer 16 using a pressure sensitive adhesive double coated tape so as to attain uniform application of pressure and electric insulation. As the rubber plates 19 and 20, EPT rubber plates of 50 x 50 mm and 5.0 mm in thickness having a hardness of 60 degrees were used.

Each test sample was connected to the LCR meter in the same manner as described hereinbefore, and sandwiched between tensile strength-compression strength measuring members 17 and 18 of an all-purpose tensile-compression tester, TCM-1000, made by Shinko Tsusin Kogyo K.K. Then, measurement was conducted at a compression-drawing cycle mode of 1 mm per minute up to 240 kg using a load cell of 500 kg in a full scale to obtain graphs shown in Figs. 15 to 18.

Additionally, Fig. 15 is a graph showing the results of the measurement of the test sample for Example 4, Fig.16 for Comparative Example 3, Fig. 17 for Comparative Example 4, and Fig. 18 for Comparative Example 5.

It has been found from Figs. 15 to 18 that the test sample for Example 4 showed the least hysteresis, and the test sample for Comparative Example 5 showed the largest hysteresis and that this was in a close relation to the physical properties of the vulcanized moldings shown in the lower part of Table 2. This test results reveal that it was only the test sample of Example 4 that showed a hysteresis of 1 PF.

Table 2

		Ex.4	Comp. Ex. 3	Comp. Ex. 4	Comp. Ex. 5
Catalogue described Matter	Grade	#KE9511*	#XE951-U*	#XE152-U*	#KE650-U*
	Main Use	Industrial material with high resistance against flexing fatigue	Food packing; Rubber stopper for medical use; Industrial packing	Transparent tubes for beverage; For other foods	Boots; For sealing use such as O-rings
	Hardness	50 deg.	50 deg.	50 deg.	50 deg.
	*1	4.6 %	10.0 %	18.0 %	36.0 %
Actual Measurements	Hardness	50 deg.	49 deg.	50 deg.	51 deg.
	tan δ	0.016	0.038	0.046	0.065
	Impact resilience	83 %	68 %	57 %	41 %
	*2	2.5 %	6.2 %	12.3 %	18.7 %

*: manufactured by Shin-etu Kagaku K.K.
*1: compression set mesured at 150 C for 22 hrs.
*2: compression set mesured at 25 C for 22 hrs.

Example 5 and Comparative Examples 6 and 7

Similar tests were conducted using 50-deg. polyurethane rubbers of caprolactone series described in Table 3. As polyol, a bifunctional product of a trade name of PCL220N (made by Daisel Ltd.) having a molecular weight of 2000 and both terminal hydroxyl groups was used. After dehydrating this polyol at 120°C, it was mixed with an MDI isocyanate product of a trade name of Milionate MT (made by Nippon Polyurethane K.K.) and a cross-linking agent, TMP, and the resulting mixture was poured into a mold for producing a pipe-shaped product, then heated at 100°C for 12 hours in an electric furnace to harden. Thus, there were prepared test materials.

The materials were finish-abraded into a thickness of 1.5 mm using an abrasion machine for rubber, and cut into sheets. Strip pieces of the same dimensions as in Example 3 were prepared and disposed at regular intervals to prepare test samples of Example 5 and Comparative Examples 6 and 7 shown in Fig. 3(b). These test samples were subjected to the tests in the same manner as in Example 1 to obtain graphs shown in Fig. 19 to 21.

Additionally, Fig. 19 is a graph showing the results of Example 5, and Figs. 20 and 21 the results of Comparative Examples 6 and 7, respectively.

By comparing the results with respect to the physical properties in Table 3, it was found that the test sample of Example 5 having good tan δ, impact resilience and compression set was usable as a pressure sensor. Thus, it was confirmed that materials having physical properties in accordance with the present invention were also obtained by using polyurethane rubber.

Additionally, in each of the above Examples, descriptions are made by reference to the case where three electrode layers are provided. It is also possible to provide 5- or more odd-number electrode layers in parallel to each other, between each two of which may be provided a dielectric layer, or two electrode layers may be provided in parallel to each other between which a dielectric layer is disposed.

Table 3

		Ex. 5	Comp. Ex. 6	Comp. Ex. 7
Formulation	PCL 220N	100.0		
	Milionate MT	21	23	25
	TMP	2.6	3.0	3.5

Table 3 (continued)

		Ex. 5	Comp. Ex. 6	Comp. Ex. 7
Actual Measurement	Hardness	60 deg.	59 deg.	60 deg.
	Impact resilience	80 %	56 %	42 %
	tan δ	0.015	0.039	0.064
	Compression set	2.1 %	8.5 %	36.2 %

Another embodiment of the present invention is specifically described below.

In an embodiment shown in Fig. 22, first dielectric pieces 9' and second dielectric pieces 10' are provided between a first electrode layer 53 and a second electrode layer 54. The first dielectric pieces 9' and the second dielectric pieces 10' are disposed so that their longitudinal direction crosses at right angles to the paper plane and have a parallelogramic section taken along the direction crossing at right angles to the longitudinal direction.

Each of the first dielectric pieces 9' is inclined rightward at an angle of α° with respect to the second electrode layer 54, whereas each of the second dielectric pieces 10' is inclined leftward at an angle of α° with respect to the second electrode layer 54. The first dielectric pieces 9' and the second dielectric pieces 10' are alternately provided, with the number of the first dielectric pieces 9' being the same as the number of the second dielectric pieces 10'. Additionally, although the number of the first dielectric pieces 9' is the same as the number of the second dielectric pieces in Fig. 22, the numbers may be slightly different from each other.

When pressure is applied to the first electrode layer 53, forces to shift the first electrode layer 53 and the second electrode layer 54 in directions different from the pressure-applying direction (vertical direction in Fig. 22) are cancelled out owing to the above-described structure, and the shearing deformation can effectively be utilized. That is, the above-described structure serves to prevent the first electrode layer 53 and the second electrode layer 54 from shifting in a horizontal direction, thus a pressure sensor showing a wide region where capacitance changes in a linear manner being provided.

In addition, a ratio of width (W1) of each of the first dielectric pieces 9'(or second dielectric pieces 10') in contact with the first electrode layer 53 (or second electrode layer 54) to thickness (T1) of the first dielectric layer 9 (or second dielectric layer 10), i.e., W1/T1, is preferably 2/3. As to thickness of the first dielectric pieces 9' and the second dielectric pieces 10' is preferably 0.2 mm to 5 mm, particularly preferably 1.5 mm, in view of ease of their production and minimization of scattering in sensitivity of produced pressure sensors.

Additionally, in practicing this embodiment of the present invention, as is shown in Fig. 23, N (N = 5 in Fig. 23) first dielectric pieces 9' inclining at an angle of α° rightward with respect to the second electrode layer 54 may be provided on one side, while N (N = 5 in Fig. 23) second dielectric pieces 10' inclining at an angle of α° leftward with respect to the second electrode layer 54 may be provided on the other side.

Further, in order to obtain a practical pressure sensor, a structure wherein two dielectric layers of dielectric layer 14A and dielectric layer of 14(B) and three electrode layers 15', 16' and 17' sandwiching them are disposed as shown in Fig. 24(A) is preferred since it is scarcely affected by ambient atmospheric charge upon use, which serves to reduce error of capacitance upon measurement.

Further, in uses where pressure is applied to the pressure sensor in a non-specific direction, a structure as shown in Fig. 24(B) wherein the upper dielectric layer 14A and the lower dielectric layer 14B are so disposed that dielectric pieces constituting respective dielectric layers cross at right angles to each other is desirable.

Additionally, in the case of using a rubber elastic body with a certain formulation where a load to be measured is so large that the dielectric layer pieces with a parallelogramic section is deformed out of the region with a good linearity or where the parallelogramic dielectric layer pieces might possibly be broken due to too large deformation of the dielectric layer pieces, it may also be possible to increase electrode layers 38 and dielectric layers 39 in number to form a multi-layered structure as shown in Fig. 25(A) to (E) which serves to reduce the pressure per dielectric layer and prevent the pressure sensor from being damaged upon a maximum load being applied thereto. In such case, it suffices to dispose odd-number electrode layers 38 parallel to each other and each of the dielectric layers 39 is sandwiched between each two of them, with odd-number order electrode layers 38 (excluding the dielectric layers) being connected to each other with a wiring cord in a parallel connection and connected to one terminal of an alternating power source, and even-number order electrode layers 38 (excluding diectric layers) being connected to each other with a wiring cord in a parallel connection and connected to the other terminal of the alternating power source.

In order to prevent unnecessary shift at a pressure-applied area due to searing deformation, the sectional shape may not be a parallelogram, and dielectric pieces with various sections 41, 42, 43, 44, 45, and 46 as shown in Fig. 26 (A) to (D) may also be used, with respective dielectric pieces 41 to 46 being used almost in the same number. That is, as is shown in Fig. 26(A), the sectional shape of the dielectric pieces may be that wherein α = 45° and β = 90°. Thus,

the dielectric pieces may have any sectional shape as long as α is in the range of from 30 to 85° and β is in the range of from 90 to 145°, and those designated by numeral 43 to 46 in Fig. 26(B) and (C) may be employed.

In addition, although, in Fig. 26(A) to (C), the dielectric pieces of different sections are alternately provided (i.e., in the order of a dielectric piece 41 and a dielectric piece 42, or of a dielectric piece 43 and a dielectric piece 44) in a horizontally simmmetrical manner with respect to the sectional shape, it is also possible to provide N (N = 3 in Fig. 26) dielectric pieces 41 directed in the same direction on one side, and N (N = 3 in Fig. 26) dielectric pieces 42 on the other side so that the sectional shapes thereof are symmetrical with each other.

Additionally, in Fig. 26(A) to (D), numeral 50 designates a first electrode layer, and 40 a second electrode layer.

The manner of disposing the dielectric layers is not limited to those described above, and those shown in, for example, Figs. 32 and 33 may also be employed. That is, dielectric pieces 47 and 48 may be provided at a predetermined angle of γ to side 35A of the second electrode layer 35, with the dielectric pieces 47 and 48 being disposed in a symmetrical manner with respect to the sectional shape.

Further, as is shown in Figs. 34 and 35, a pair of dielectric pieces 47 and 48 may be disposed so that the upper ends of the pieces in Fig. 34 are more spaced than the lower ends, with this relation being alternately reversed as shown in Fig. 34.

Still further, as is shown in Figs. 36 to 38, a pair of dielectric pieces 47 which have a continuously decreasing width in the downward direction in Fig. 36 (i.e., dimension in the horizontal direction in Fig. 36) may be provided, with this relation being alternatelyreversed as shown in Fig. 36.

As to the materials for the dielectric pieces to be used, it is important for them to have a high impact resilience and a small compression set, and those with a high impact resilience and a small compression set such as natural rubber, IR, BR, polyurethane rubber, silicone rubber, etc. may be employed.

A lower rubber hardness provides a higher spring constant, whereas a higher rubber hardness provides a higher spring constant. Thus, for example, dielectric pieces for manufacturing various general-purpose pressure sensors whose maximum measurable loads are from about 10 kg to 1000 kg may use rubbers with a rubber hardness of 20 degrees to 80 degrees in terms of scale A described in JIS-K-6301 taking the spring constant, shape, area, and other factors into consideration.

Assuming the case of manufacturing a pressure sensor whose maximum measurable load is about 100 kg and which is designed for measuring pressure force of rubber rolls in a printng press, a rubber with a rubber hardness of 30 degrees to 40 degrees in terms of scale A described in JIS-K-6301 is preferably used for the dielectric pieces and, as a material for the dielectric layer, a silicone rubber is one of the optimal materials due to its good rubber elasticity, less change in spring constant with time, and less change in spring constant upon temperature being changed.

Examples 6 and 7, and Comparative Examples 8 to 10

In order to confirm the relation between shape and output, the following tests were conducted using the same rubber material, the same rubber hardness, and the same area to which pressure was applied.

As a rubber for the dielectric layer, polybutadiene rubber having the formulation shown in Fig. 4 was used. This was subjected to electrical heat press molding under the conditions of 165°C x 15 minutes and 200 kg/cm^2 to prepare a vulcanized rubber sheet of 1.5 mm in thickness, 150 mm in width, and 200 mm in length. This sheet had a rubber hardness of 40 degrees in terms of scale A described in JIS-K-6301.

Then, this rubber sheet was cut into 5 kinds of strip pieces (dielectric pieces) respectively having sectional shapes shown in Table 5, No. A to No. E (shapes taken along the plane crossing at right angles to the longitudinal direction) without changing thickness and length. The strip pieces No.A to No.E were respectively adhered to the first electrode layer 15', second electrode layer 17', and third electrode layer 17' shown in Fig. 24(C) parallel to each other. Additionally, each electrode was made of an aluminum plate of 200 mm in width, 250 mm in length, and 5 mm in thickness. This adhesion was conducted as shown in Fig. 24(A) so that an area to which pressure is to be applied of the dielectric layers 14A and 14B [sum of the contact areas between one side of the dielectric piece constituting the dielectric pieces 14A (or 14B) and the electrode layer] was equally 60 cm^2 with No.A through No.E (see Table 6) using the aforesaid strip pieces (dielectric pieces) in the number described in Table 6 and an urethane series two-part adhesive.

Thus, there were prepared 5-layered test samples having two dielectric layers and three electrode layers as shown in Fig. 27(A) to (E), i.e., test sample No. T-1 (Comparative Example 8), No. T-2 (Comparative Example 9), No. T-3 (Comparative Example 10), No. T-4 (Example 6), and No. T-5 (Example 7).

Additionally, numerals 27' and 29' in Fig. 27 (A) to (E) represent a first dielectric layer and a second dielectric layer, respectively. Signs 27A and 27B in Fig. 27(D) represent a first dielectric piece and a second dielectric piece in the first dielectric layer 27', respectively, and signs 29A and 29B represent a first dielectric piece and a second dielectric piece in the first dielectric layer 29', respectively. Signs 27C and 27D in Fig. 27(E) represent a first dielectric piece and a second dielectric piece in the first dielectric layer 27', respectively, and signs 29C and 29D epresent a first dielectric piece and a second dielectric piece in the first dielectric layer 27', respectively. Additionally, Fig. 24(A) shows an example

prepared by using the strip pieces 14A (14B) shown in Fig. 24(D) (No. T-3).

Then, each of the test samples No. T-1 to T-5 was connected to a precision LCR meter, HP4284, made by Huret Paccard Co. in such manner that , as is shown in Fig. 28, the first electrode layer 15' and the third electrode layer 17' were connected to one output terminal 22' of the precision LCR meter via a connecting portion 20' using wire cords 18' and 19', respectively, and the remaining second electrode layer 16' was connected to the other output terminal 23' of the LCR meter through a wire cord 21'. An alternating current voltage of 1 MHz 6 V was applied thereacross, and a 20-kg weight or weights 25' were placed in piles on each of the samples (first electrode layer 15') (see Fig. 28) to apply loads of 0 kg, 20 kg, 40 kg, 60 kg, 80 kg, and 100 kg. Capacitance of each test sample under each load was measured. The results thus obtained are shown in Table 7 and Fig. 29.

As is apparent from Table 7 and Fig. 29, changing amounts of capacitance with the test sample of Example 6 (sectional shape: diamond shape) and the test sample of Example 7 (sectional shape: parallelogram) are clearly different from those with the test samples of Comparative Examples 8 to 10 having the same contact area with the electrode layer and undergoing simple compression, thus the test samples of Examples 6 and 7 being proved to have a sensitivity several times as much as the test samples of Comparative Examples 8 to 10. In the case of simple compression, the test sample of Comparative Example 9 (W/T = 2.0) is said to be a limit of not suffering abnormal deformaton or falling down upon being pressed, thus the test sample of Comparative Example 10 is not used in simple compression. To compare to the test sample of Comparative Example 9 which is most popular for simple compression, the test sample of Example 8 (W/T = 1) was found to show a 4-fold changing amount, and the test sample of Example 7 (W/T = 2/3) a more than 5-fold changing amount.

Table 4

Compounded Chemicals	Parts by Weight
JSR-BR-01	100.0
Active zinc flower	5.0
Stearic acid	0.5
Aging inhibitor 3C	0.5
Percumyl D-40	6.0
Diana PX-50	8.0
Nipsil VN3	2
Precipitated sulfur	1.0

Table 5

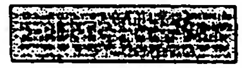
No.	Sectional Shape of Dielectric Pieces	
A	Rectangle; 1.5 mm thick; 6 mm wide	
B	Rectangle; 1.5 mm thick; 3 mm wide	
C	Rectangle; 1.5 mm thick; 1.5 mm wide	
D	45 deg. Diamond; 1.5 mm thick; 1.5 mm wide	
E	45 deg. Parallelogram; 1.5 mm thick; 1.0 mm wide	

Table 6

	Shape of Rubber used in Each Test Sample (Dielectric Layer described in Table 5)	Number of Rubber per Layer of Sample	Pressure-applied Area
Comp. Ex. 8 (No.T-1)	No. A (rectangle)	5	60 cm^2
Comp. Ex. 9 (No.T-2)	No. B (rectangle)	10	60 cm^2
Comp. Ex. 10 (No.T-3)	No. C (square)	20	60 cm^2
Example 6 (No.T-4)	No. D (diamond)	30	60 cm^2
Example 7 (No.T-4)	No. E (parallelogram)	30	60 cm^2

Table 7

	Test Results for Examples 6 and 7, and Comparative Examples 8 to 10 (Change in capacitance (Cp) for respective loads; and rate of change taking change in Comparative Ex. 8 as 1; provided that numerals are presented in terms of pico-farad (Cp))										
Load	0kg	20 kg		40 kg		60 kg		80 kg		100 kg	
	ΔCp	ΔCp	*	ΔCp	*	ΔCp	*	ΔCp	*	ΔCp	*
Comp. Ex. 8 (No.T-1)	0.0	4.8	1.0	9.2	1.0	13.3	1.0	16.8	1.0	18.5	1.0
Comp. Ex. 9 (No.T-2)	0.0	12.0	2.5	22.4	2.4	31.6	2.4	39.0	2.3	43.6	2.4
Comp. Ex. 10 (No.T-3)	0.0	15.8	3.3	30.1	3.3	43.2	3.2	54.1	3.2	61.4	3.3
Example 6 (No.T-4)	0.0	32.0	6.7	63.1	6.9	95.6	7.2	129.6	7.7	159.6	8.6
Example 7 (No.T-5)	0.0	38.3	8.0	75.7	8.2	114.7	8.6	154.5	9.2	191.0	10.3

*: rate of change

Examples 8 to 10, and Comparative Examples 11 and 12

As a test for making practicable by more increasing the rate of change in capacitance, tests were conducted using silicone rubbers having a good heat resistance and a good cold resistance and a less temperature dependence to examine how rubber hardness, pressure-applying area, and shape exert influences on capacitance in comparison with standard simple compression shape. Table 8 describes sectional shape of dielectric pieces constituting the dielectric layers of respective Examples and Comparative Examples, sectional shapes of tested samples, and contact areas between the dielectric pieces and the electrode layer.

The used silicone rubber is a dimethylsilicone rubber of existing grade. That is, #KE941U (40 deg.) and #KE931U (30 deg.) made by Shin-etu Kagaku K.K. were compounded in a manner specified by the manufacturer, and kneaded in an oven roll to prepare a raw rubber. Three test samples for No. T-8 (Example 8), No. T-9 (Example 9), and No. T-10 (Example 10) which were expected to show large change in capacitance from the results shown in Table 8 were prepared as follows.

That is, as is shown in Figs. 30(A) and (B), dielectric pieces 31 and 34 of Examples 8 to 10 were disposed on and beneath a second electrode layer (35) composed of a 0.2-mm thick stainless steel sheet, SUS#301, in a symmetrical manner with respect to sectional shape, and adhered via an adhesive using a newly made special press molding under the molding conditions of 170°C, 10 minutes, and 200 kg/cm^2 to prepare intermediate products. Fig. 30(A) is a plan view from above of the intermediate products, and Fig. 30(B) a side view thereof.

Each of the intermediate products was adhesively sandwiched so that a 1-mm thick, aluminum-made first electrode layer 36 was on the upper side, and a 1-mm thick, aluminum-made second electrode layer 37 on the lower side through an RTV silicone rubber of 30 deg. in rubber hardness to prepare test samples shown in Fig. 30(C). Fig. C is a sectional view of the test sample.

Two test samples of Comparative examples 11 and 12 for comparison having a simple compression shape were

prepared as follows. A 1.5-mm thick press-molded sheet composed of silicone rubber was prepared in the same manner as in Example 6, and cut into strip pieces having a rectangular section as with test sample Nos. T-6 and No. T-7 in Table 8.

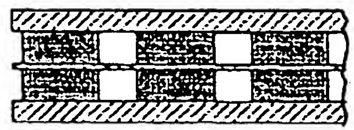
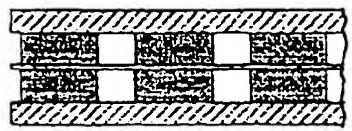
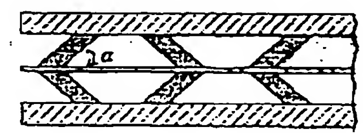
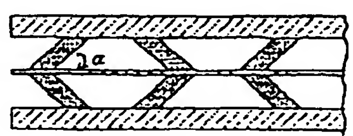
Then, the strip pieces were adhered in the same manner as in Example 6 to prepare test samples. Additionally, as an adhesive, the same RTV silicone rubber of 30 deg. in rubber hardness as used for Nos. T-8 to T-10 was used. Five kinds of the test samples for Nos. T-6 to T-10 were additionally heated in an electric furnace at 200°C for 4 hours to stabilize their physical properties.

Each of the above-described test samples was tested in the same manner as in Example 1. Results thus obtained are shown in Table 9 and Fig. 31.

It is seen from the results, that the test sample of Example 10 having a pressure-applied area of 40 cm^2 which is smaller than 60 cm^2 in Example 6, etc. and having a rubber hardness of 30 degrees shows change in capacitance of about 5 times as much as that of the test sample of average smple compression and of 40 degrees in ruber hardness (test sample of Comparative Example 11), thus much greater change in capacitance being confirmed in comparison with the conventional one.

Additionally, when a pressure sensor for measuring pressure of pressure rolls in a printing press was made using the test sample of Example 10, it showed a change of 245 PF under a load of 100 kg with an enough linearity. Thus, it becomes possible to make a pressure sensor capable of measuring up to 100 kg which is composed of a dielectric layer (made of rubber) of at least 1 PF = 0.5 kg and electrode plates and which is difficult to break and can be made inexpensively.

Table 8

	Dielectric Piece		Sectional Shape of Test Sample	Pressure-applying Area
	Rubber Hardness	Dimension and Shape of Section	Odd-number Order...Electrode Layer Even-number Order..Dielectric Layer	
Comp. Ex.11 (No. T-6)	40 deg.	Rectangle ;1.5 mm thick; 3.0 mm wide		60 cm^2
Comp. Ex.12 (No. T-7)	30 deg.	Rectangle ;1.5 mm thick; 3.0 mm wide		60 cm^2
Ex. 8 (No. T-8)	30 deg.	Parallelogram; 1.5 mm thick; 1.0 mm wide (angle of inclination $\alpha = 45°$)		60 cm^2
Ex. 9 (No. T-9)	30 deg.	Parallelogram; 1.5 mm thick; 1.0 mm wide (angle of inclination $\alpha = 45°$)		50 cm^2

(contd.)

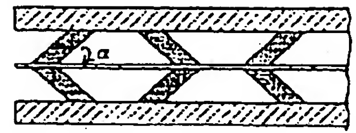
Ex.10 (No. T-10)	30 deg.	Parallelogram; 1.5 mm thick; 1.0 mm wide (angle of inclination $\alpha = 45^\circ$)		40 cm^2

Table 9

	Test Results for Examples 8 and 9, and Comparative Examples 11 and 12 (Change in capacitance (Cp) for respective loads; and rate of change taking change in Comparative Ex. 8 as 1; provided that numerals are presented in terms of pico-farad (Cp))										
Load	0 kg	20 kg		40 kg		60 kg		80 kg		100 kg	
	ΔCp	ΔCp	*	ΔCp	*	ΔCp	*	ΔCp	*	ΔCp	*
Comp. Ex. 11 (No.T-6)	0.0	12.8	1.0	24.1	1.0	33.8	1.0	40.9	1.0	46.1	1.0
Comp. Ex. 12 (No.T-7)	0.0	15.1	1.2	28.4	1.2	39.9	1.2	49.2	1.2	56.4	1.2
Example 8 (No.T-8)	0.0	39.2	3.1	75.8	3.1	117.4	3.5	152.8	3.7	187.0	4.1
Example 9 (No.T-9)	0.0	45.6	3.6	91.2	3.8	132.8	3.9	174.6	4.3	217.6	4.7
Example 10 (No.T-10)	0.0	55.2	4.3	103.6	4.3	152.8	4.5	202.3	4.9	245.0	53.3

*: rate of change.

According to the present invention, there is provided a pressure sensor capable of measuring weight or pressure with high accuracy without any complicated structure.

Claims

1. A pressure sensor which comprises a pair of electrode layers and a dielectric layer composed of a rubber elastic body positioned between the pair of electrode layers and also functioning as a spacer for the electrodes, said dielectric layer showing a tan δ at 1 to 30 Hz at a temperature of 10 to 30°C of 0.03 or less and having a rubber hardness of 20 to 80 degrees in terms of scale A according to JIS-K-6301 at 10 to 30 C.

2. The pressure sensor as described in claim 1, which has an impact resilience of 75 % or more measured according to JIS-K-6301 at 10 to 30°C.

3. The pressure sensor as described in claim 1 or 2, which has a compression set of 3 % or less measured according to JIS-K-6301 at 10 to 30°C.

4. The pressure sensor as described in one of claims 1 to 3, wherein said dielectric layer is formed by one of natural rubber, polybutadiene rubber, polyisoprene rubber, polyurethane rubber and silicone rubber.

5. A pressure sensor which comprises a first electrode layer and a second electrode layer positioned parallel to each other and a dielectric layer made of rubber elastic body in a continuous length spacing the two electrode layers from each other with one surface thereof being in a close contact with the first electrode layer and the other opposite surface thereof being in a close contact with the second electrode layer, with said dielectric layer being formed so that one of the contact surface is shifted from the other opposite contact surface when viewed in the direction crossing at right angles to the electrode layer.

6. The pressure sensor as described in claim 5, wherein said dielectric layer has an almost parallelogramic section taken along the plane crossing at right angles to the longitudinal direction of the dielectric layer.

7. The pressure sensor as described in claim 6, wherein a plane crossing at right angles to the first and the second electrode layers crosses at an angle of 30 to 85 degrees to said dielectric layer.

8. The pressure sensor as described in claim 5 or 6, wherein one side plane of the dielectric layer croses at an angle of 30 to 85 degrees to said second electrode layer, and the other opposite side plane of the dielectric layer crosses at an angle of 90 to 145 degrees to said second electrode layer.

9. The pressure sensor as described in one of claims 5 to 8, wherein said dielectric layer comprises a first dielectric layer piece and a second dielectric layer piece disposed so that, when pressure is applied to the sensor in the vertical direction with respect to the surfaces of said first and second dielectric layers, forces of shifting respective said electrode layers are cancelled out.

10. The pressure sensor as described in claim 9, wherein number of said first dielectric layer pieces is almost the same as number of said second dielectric layer pieces.

11. The pressure sensor as described in one of claims 5 to 10, wherein a quotient obtained by dividing the length of said contact surface in the direction crossing at right angles to the longitudinal direction of said dielectric layer by the distance between the first and the second electrode layers is 0.2 to 5.0.

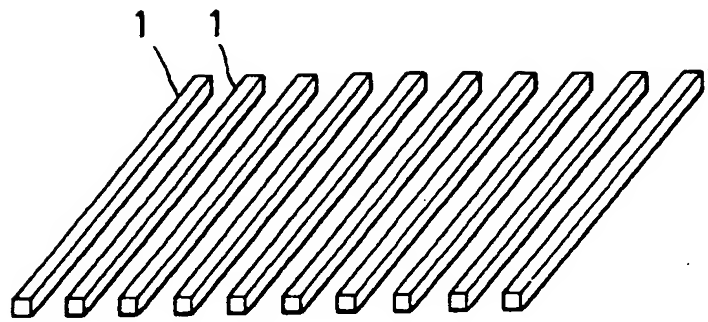
12. The pressure sensor as described in one of claims 5 to 11, wherein said dielectric layer has a rubber hardness of 20 to 80 degrees measured in terms of scale A according to JIS-K-6301.

13. The pressure sensor as described in one of claims 5 to 12, wherein distance between said first electrode layer and said second electrode layer is 0.2 to 5.0 mm.

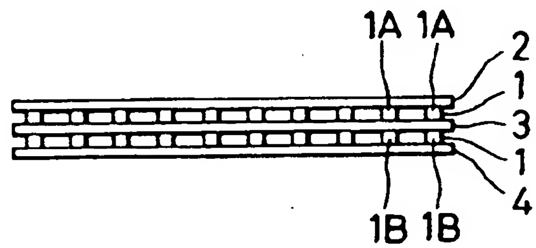
14. The pressure sensor as described in one of claims 5 to 13, wherein three or more odd-number electrode layers are provided, with said dielectric layer being closely disposed between each pair of the electrode layers.

Fig1

(a)



(b)



(c)

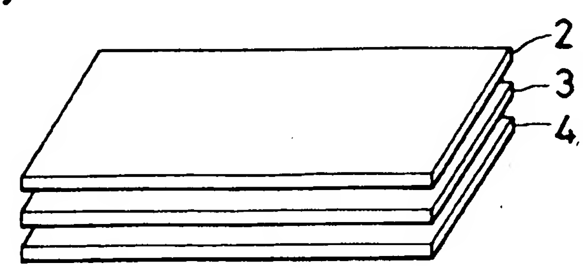


Fig2

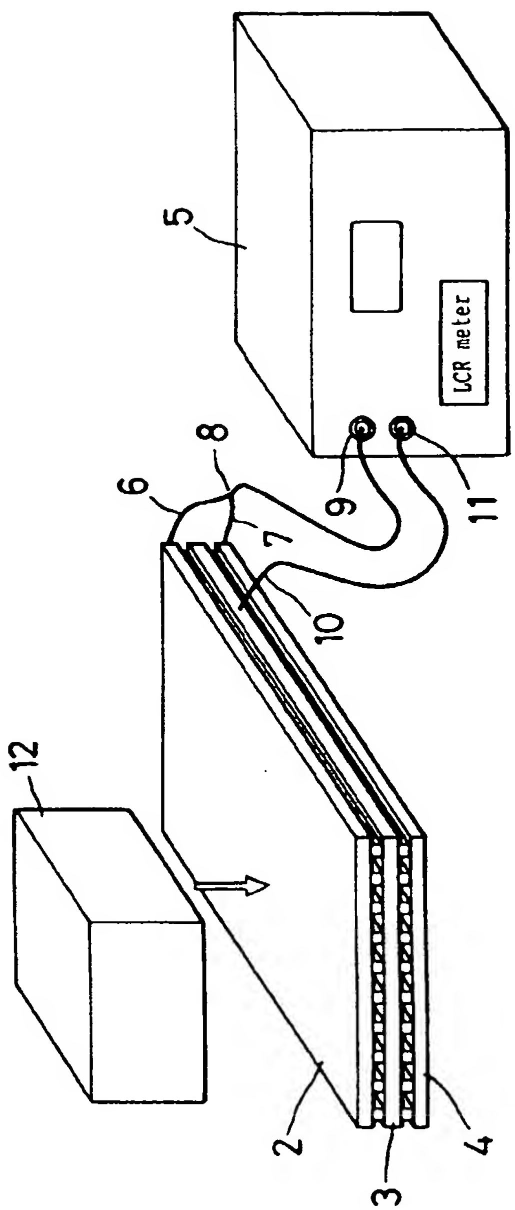


Fig3

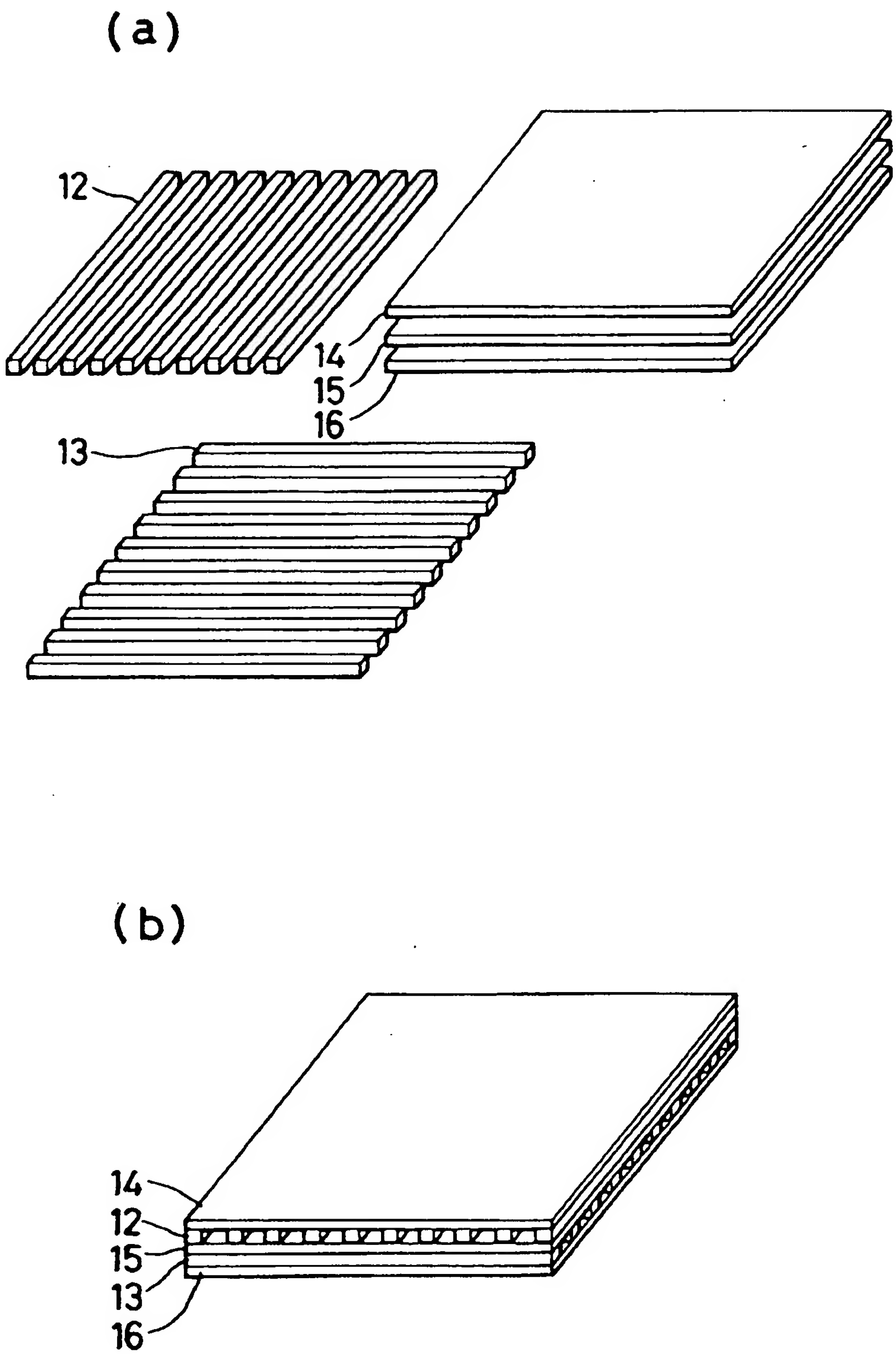


Fig4

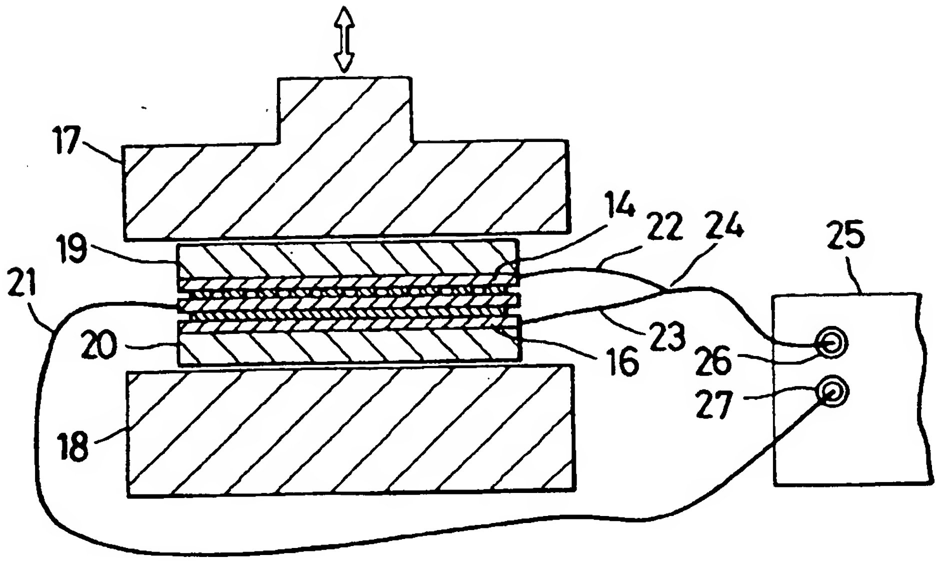

17
19
21
20
18
14
22
24
25
23
26
16
27

Fig5

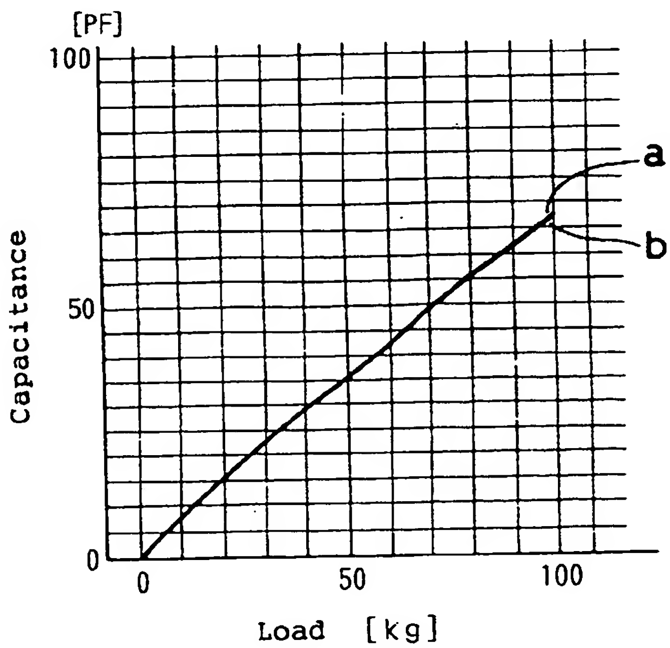

[PF]
100
50
0
Capacitance
0
50
100
Load [kg]
a
b

Fig6

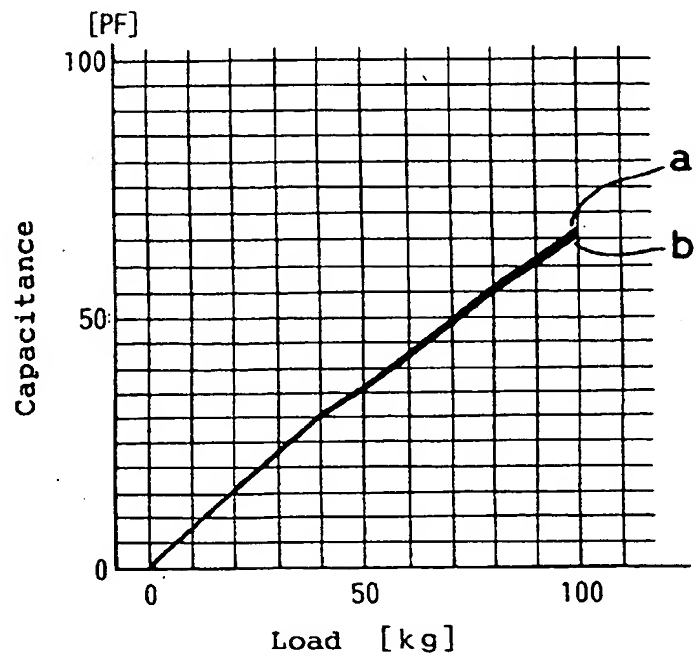

[PF]
100
50
0
Capacitance
0
50
100
Load [kg]
a
b

Fig7

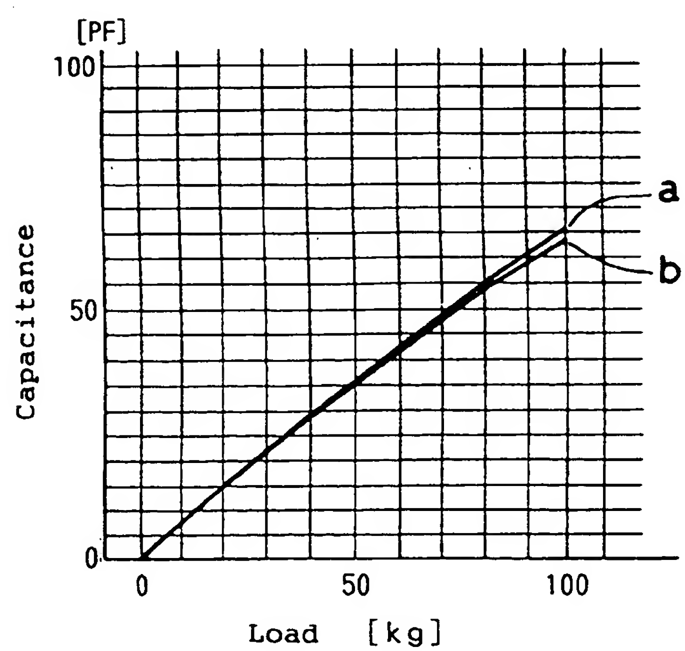

[PF]
100
50
0
Capacitance
0
50
100
Load [kg]
a
b

Fig8

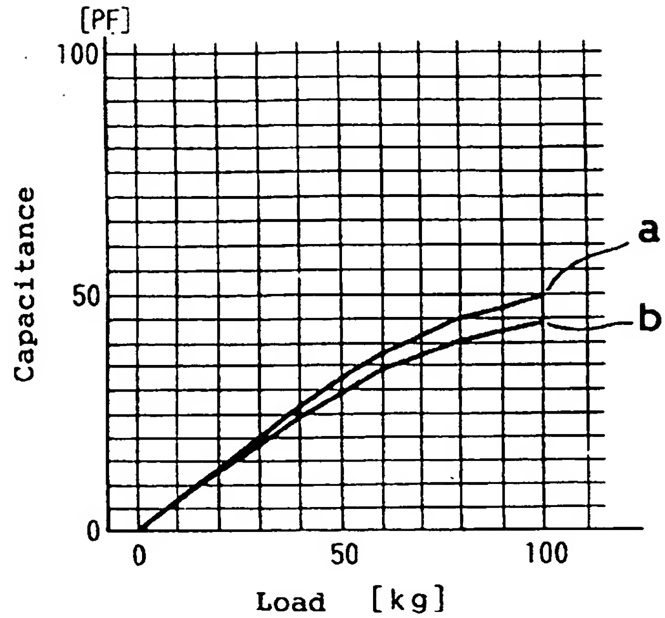

[PF]
100
50
0
Capacitance
a
b
0
50
100
Load [kg]

Fig9

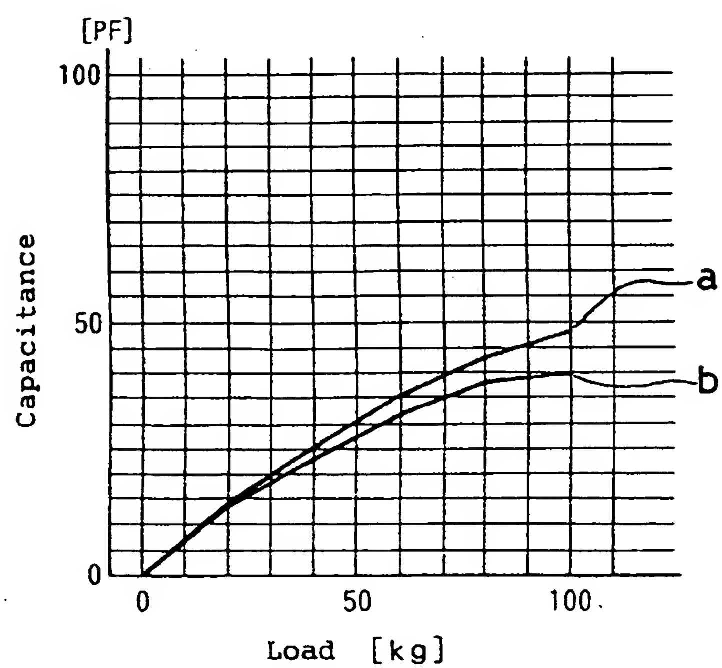

[PF]
100
50
0
Capacitance
a
b
0
50
100
Load [kg]

Fig 10

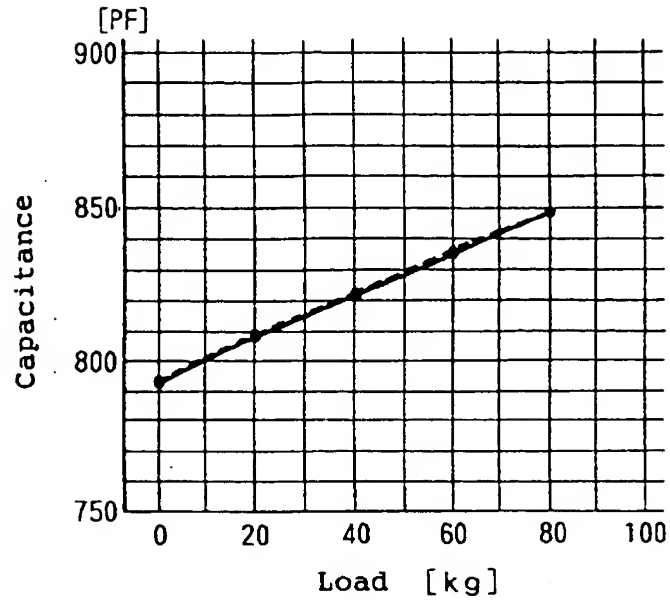

[PF]
900
850
800
750
Capacitance
0
20
40
60
80
100
Load [kg]

Fig 11

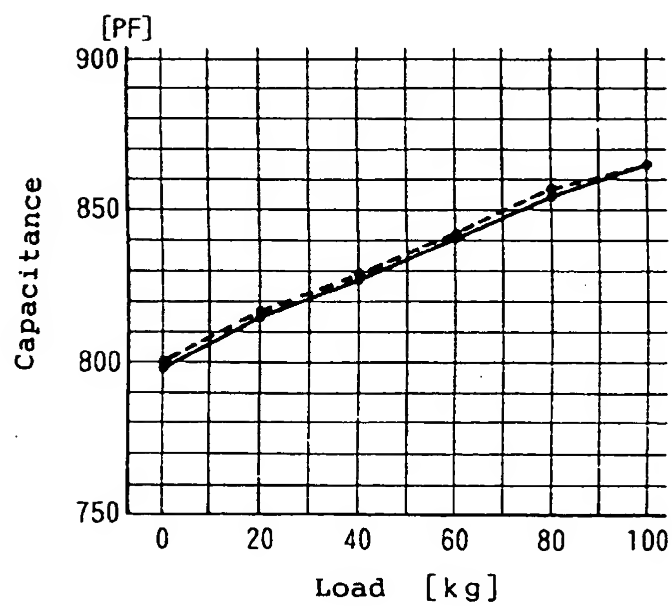

[PF]
900
850
800
750
Capacitance
0
20
40
60
80
100
Load [kg]

Fig 12

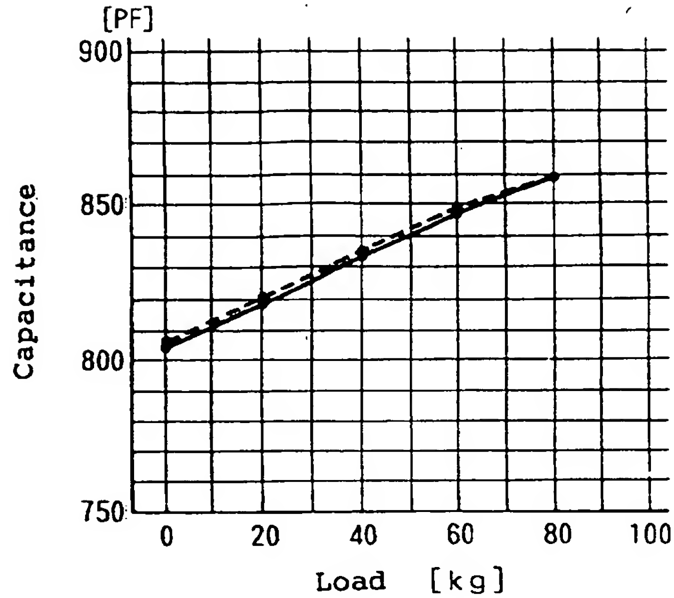

[PF]
900
850
800
750
Capacitance
0
20
40
60
80
100
Load [kg]

Fig 13

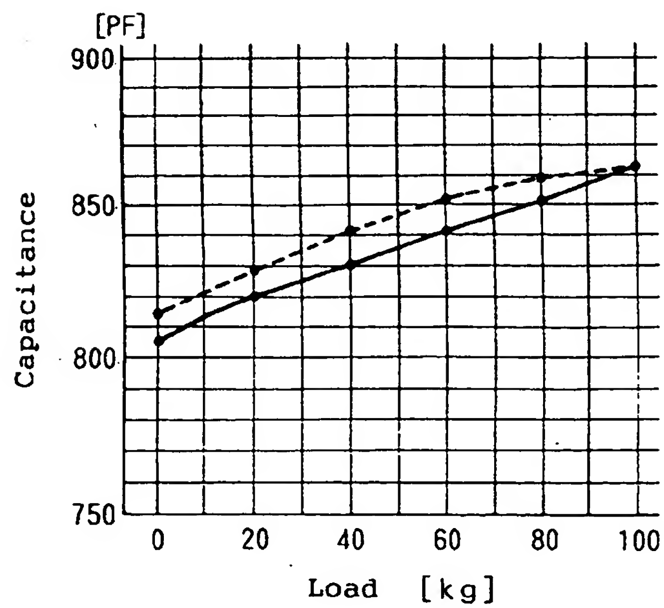

[PF]
900
850
800
750
Capacitance
0
20
40
60
80
100
Load [kg]

Fig 14

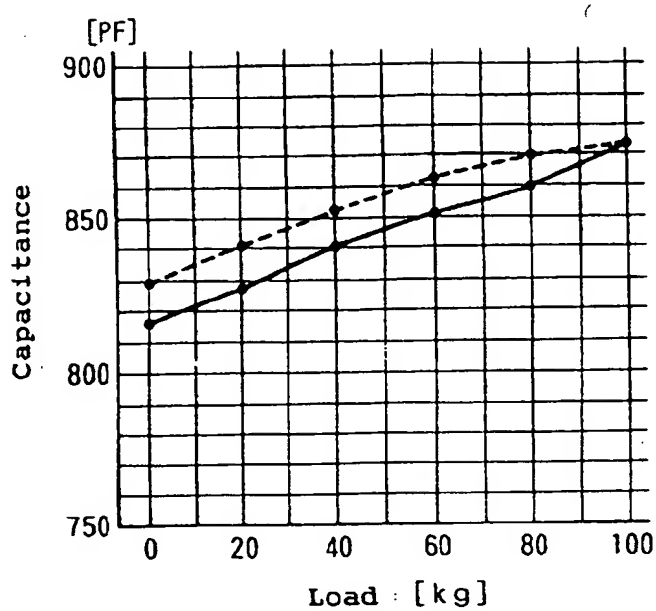

[PF]
900
850
800
750
Capacitance
0
20
40
60
80
100
Load [kg]

Fig 15

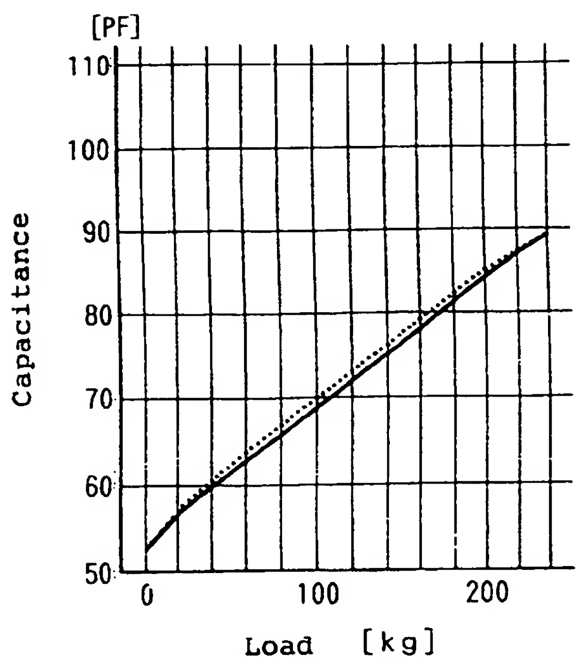

[PF]
110
100
90
80
70
60
50
Capacitance
0
100
200
Load [kg]

Fig 16

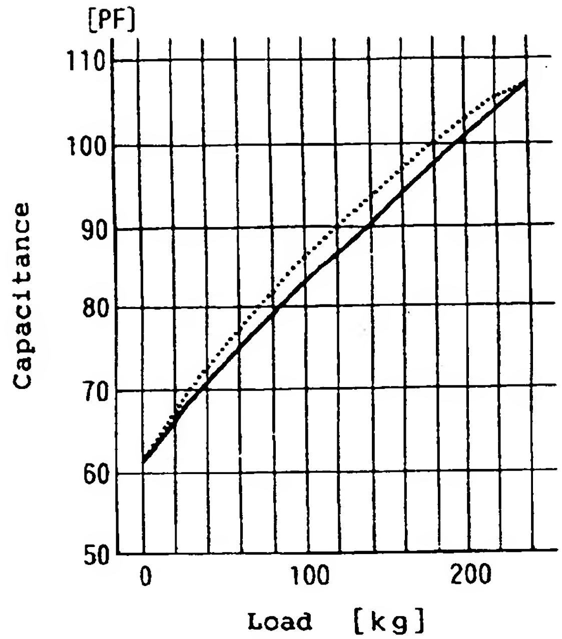

[PF]
110
100
90
80
70
60
50
Capacitance
0
100
200
Load [kg]

Fig 17

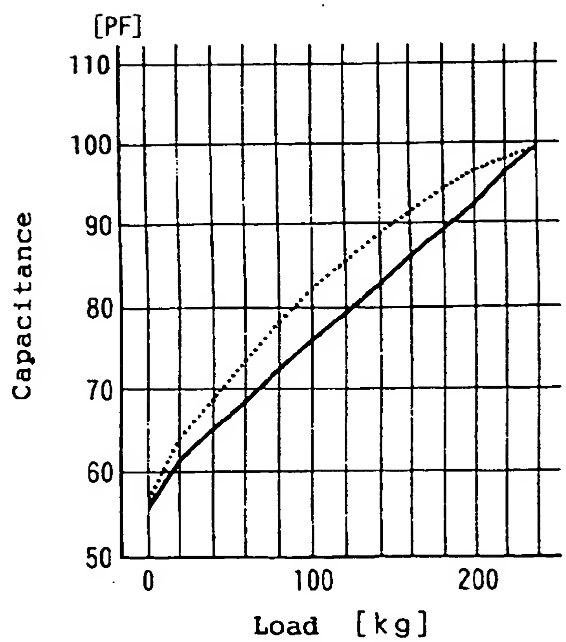

[PF]
110
100
90
80
70
60
50
Capacitance
0
100
200
Load [kg]

Fig 18

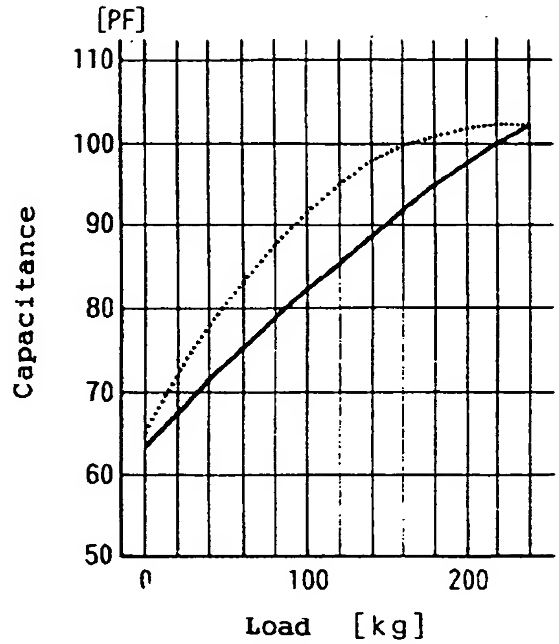

[PF]
110
100
90
80
70
60
50
Capacitance
0
100
200
Load [kg]

Fig 19

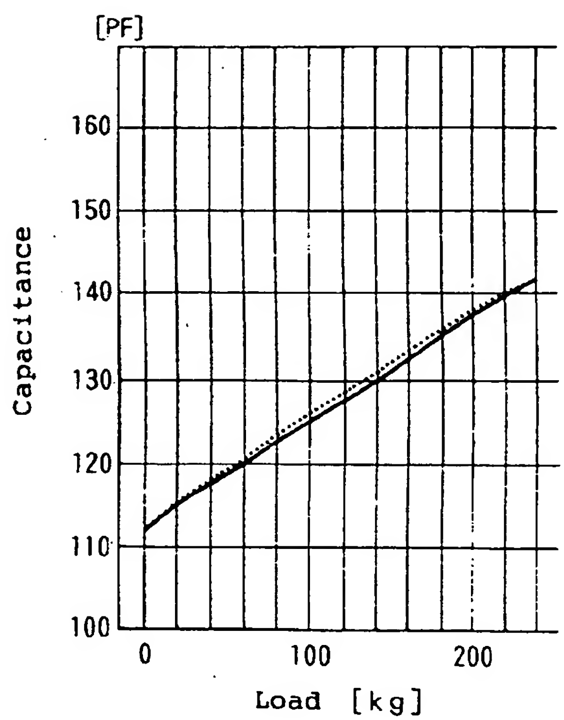

[PF]
160
150
140
130
120
110
100
Capacitance
0
100
200
Load [kg]

Fig 20

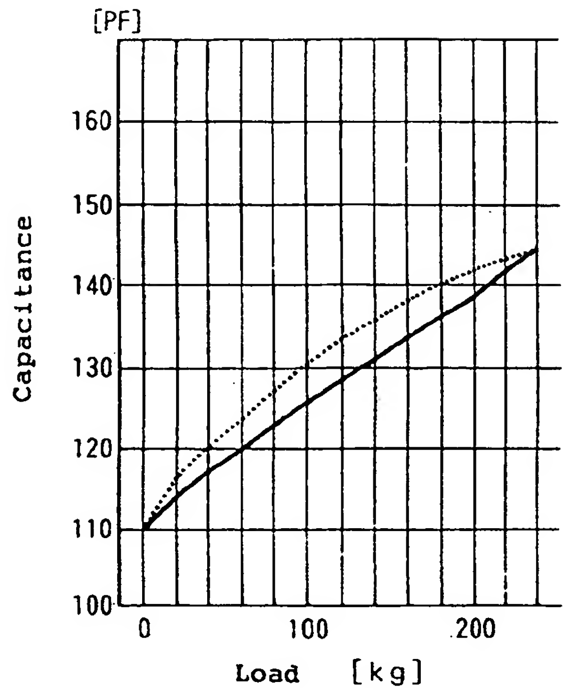

[PF]
160
150
140
130
120
110
100
Capacitance
0
100
200
Load [kg]

Fig 21

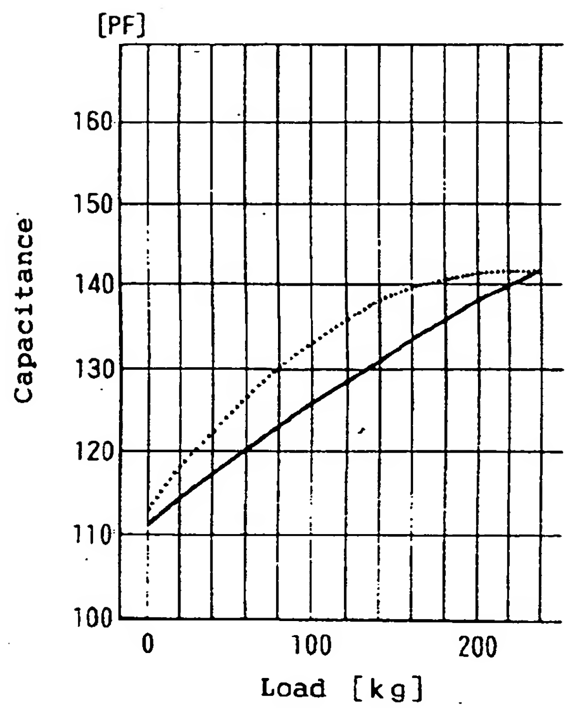

[PF]
160
150
140
130
120
110
100
Capacitance
0
100
200
Load [kg]

Fig 22

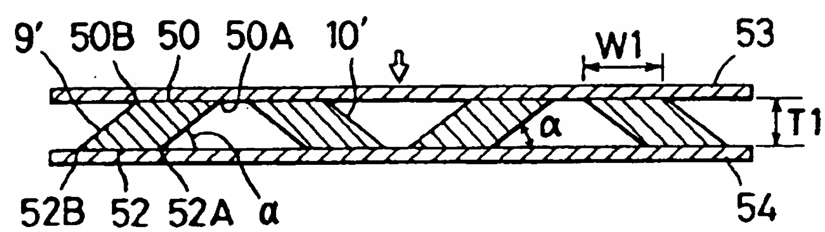


Fig 23

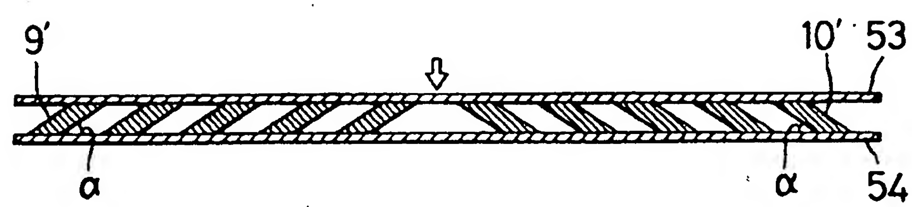
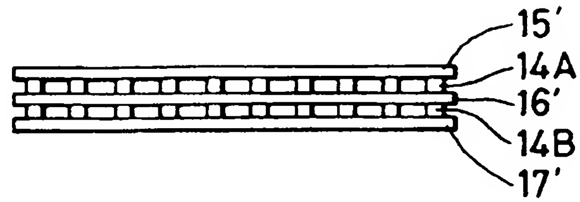
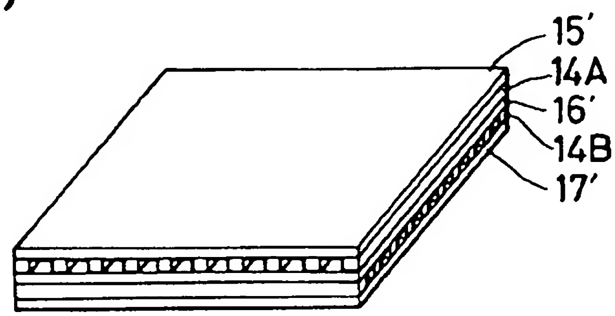


Fig 24

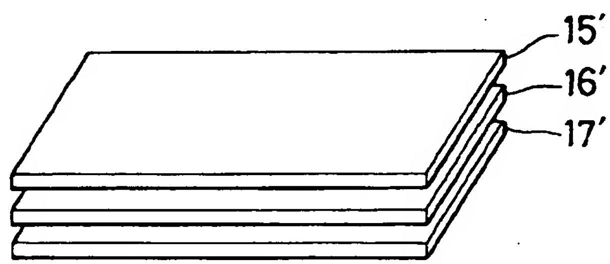
(A)



(B)



(C)



(D)

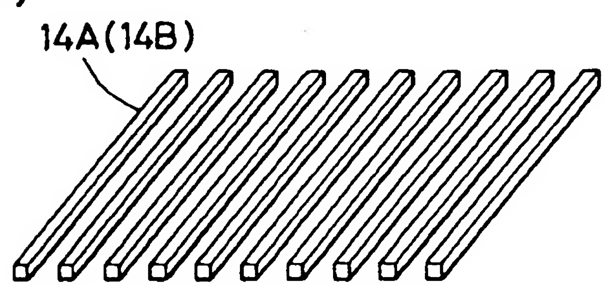
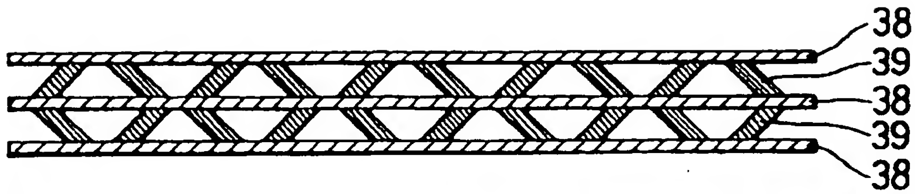
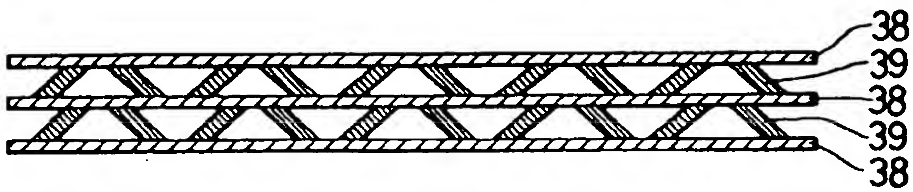


Fig 25

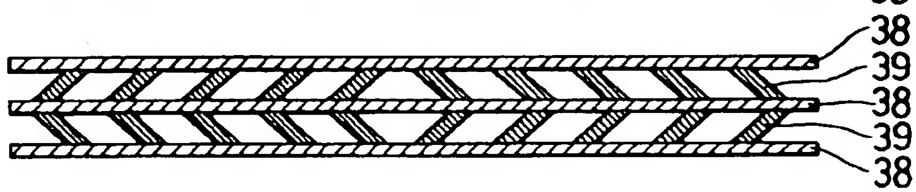
(A)


38
39
38
39
38

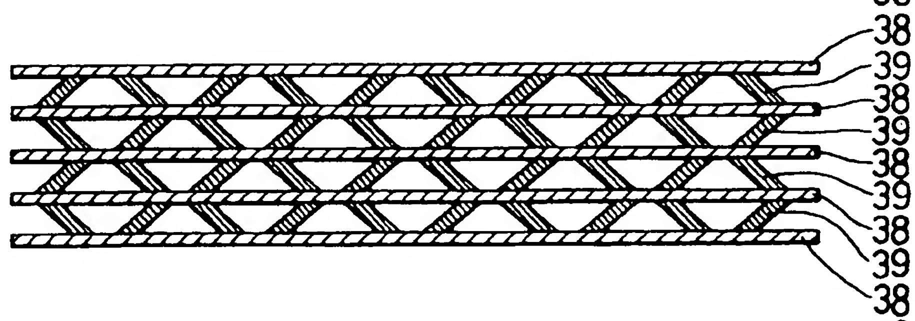
(B)


38
39
38
39
38

(C)


38
39
38
39
38

(D)


38
39
38
39
38
39
38
39
38

(E)

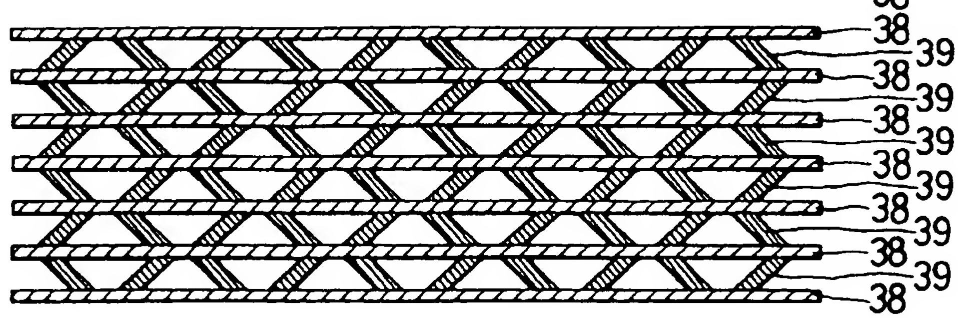

38
39
38
39
38
39
38
39
38
39
38
39
38

Fig 26

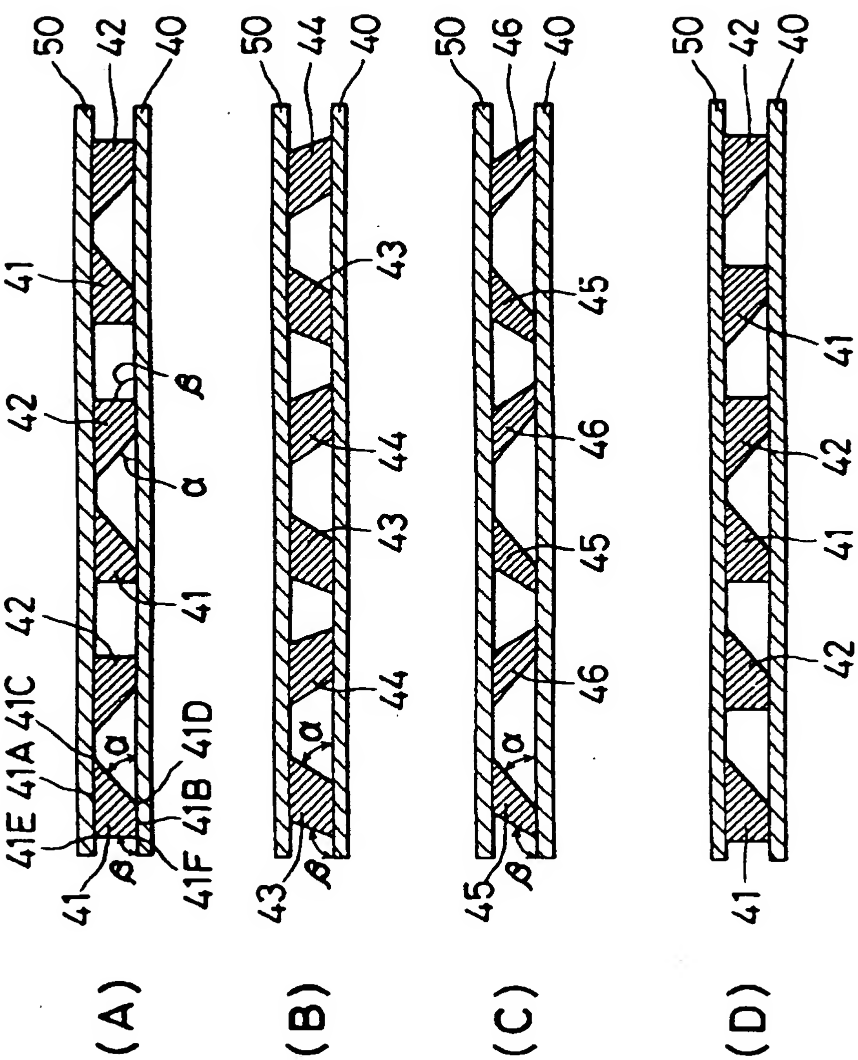

(A)
50
42
40
41
42
β
α
41
42
41E 41A 41C
α
41D
41B
41F
41
β
(B)
50
44
40
43
44
43
44
α
43
β
(C)
50
46
40
45
46
45
46
α
45
β
(D)
50
42
40
41
42
41
42
41

Fig 27

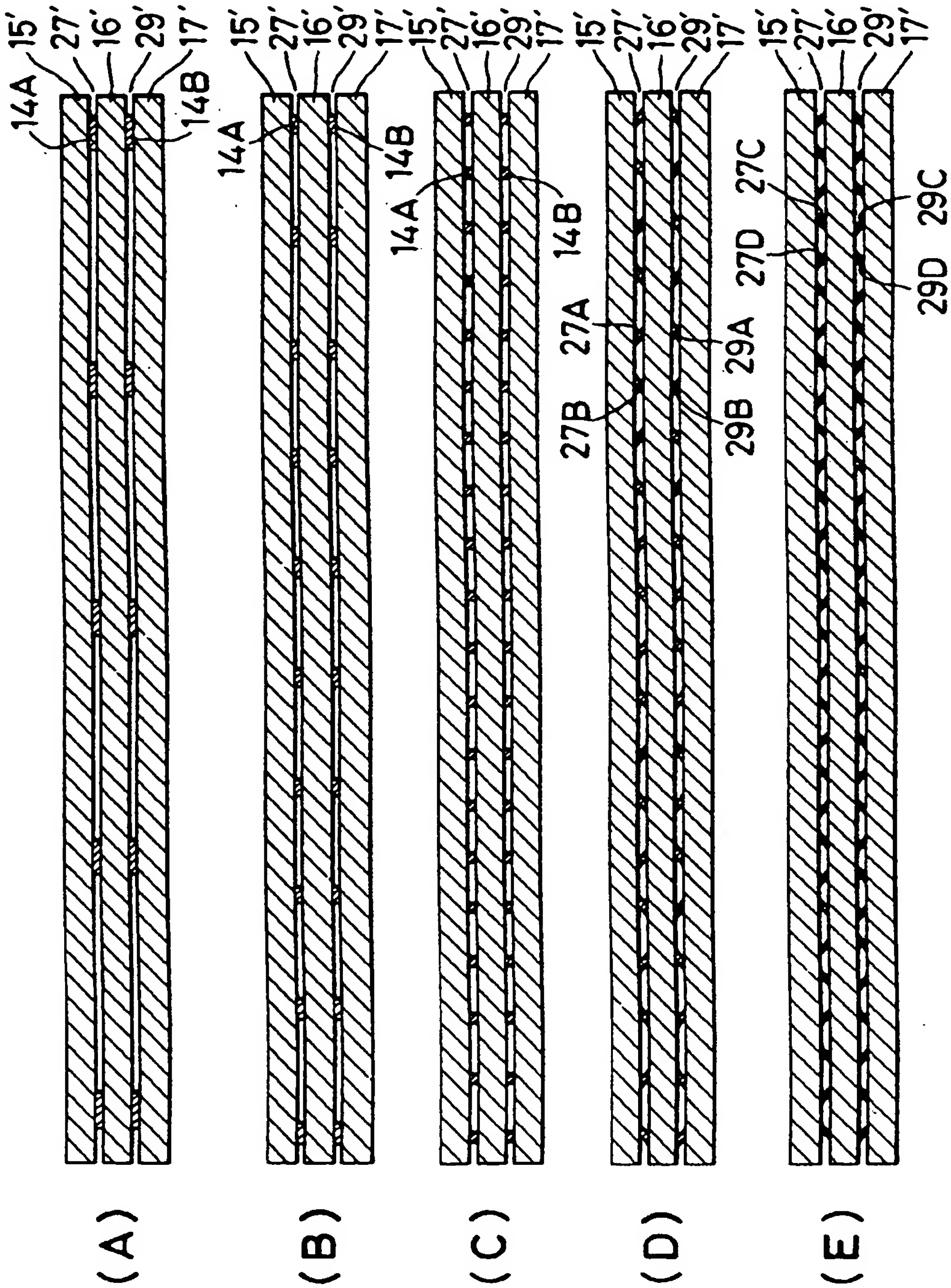


Fig 28

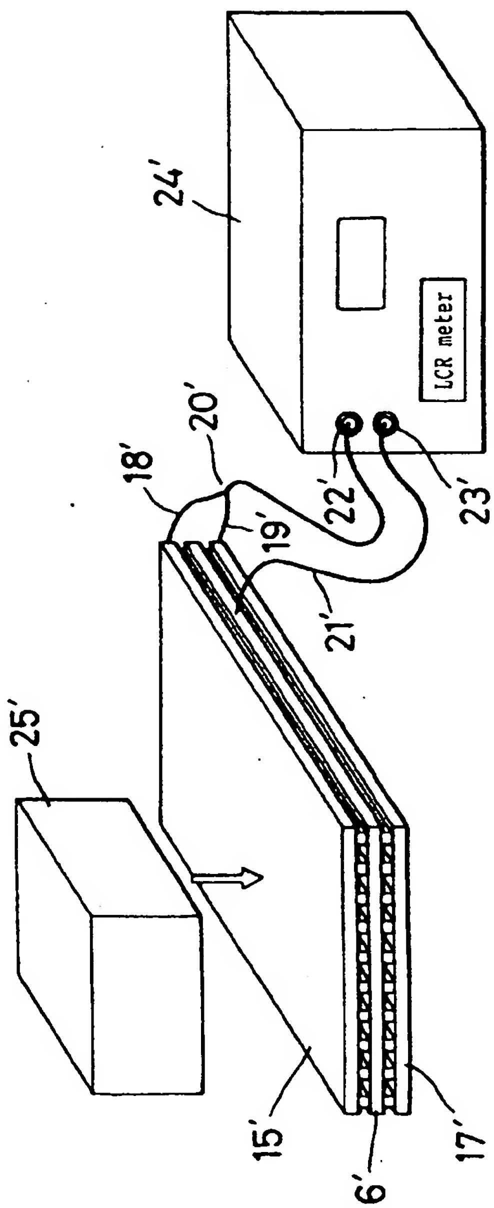


Fig 29

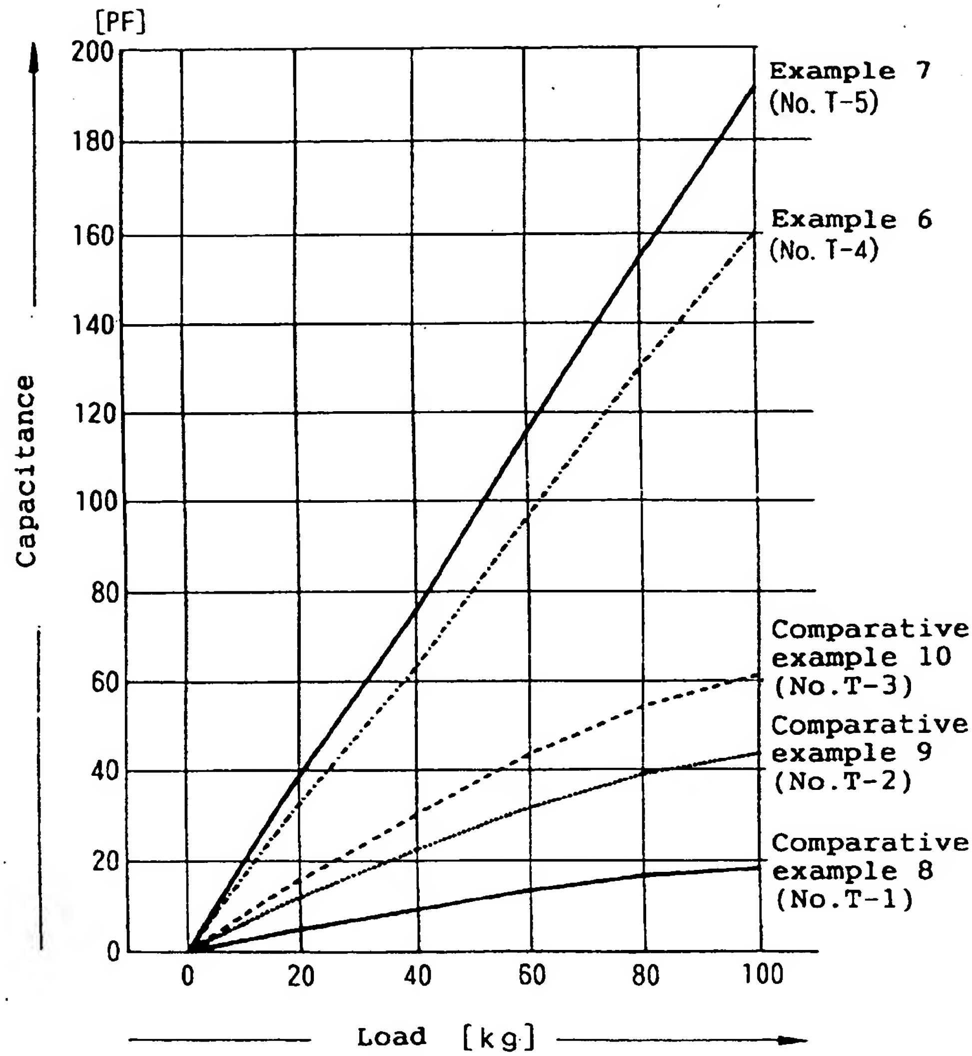

[PF]
200
180
160
140
120
100
80
60
40
20
0
Capacitance
0
20
40
60
80
100
Load [kg]
Example 7
(No. T-5)
Example 6
(No. T-4)
Comparative
example 10
(No.T-3)
Comparative
example 9
(No.T-2)
Comparative
example 8
(No.T-1)

Fig 30

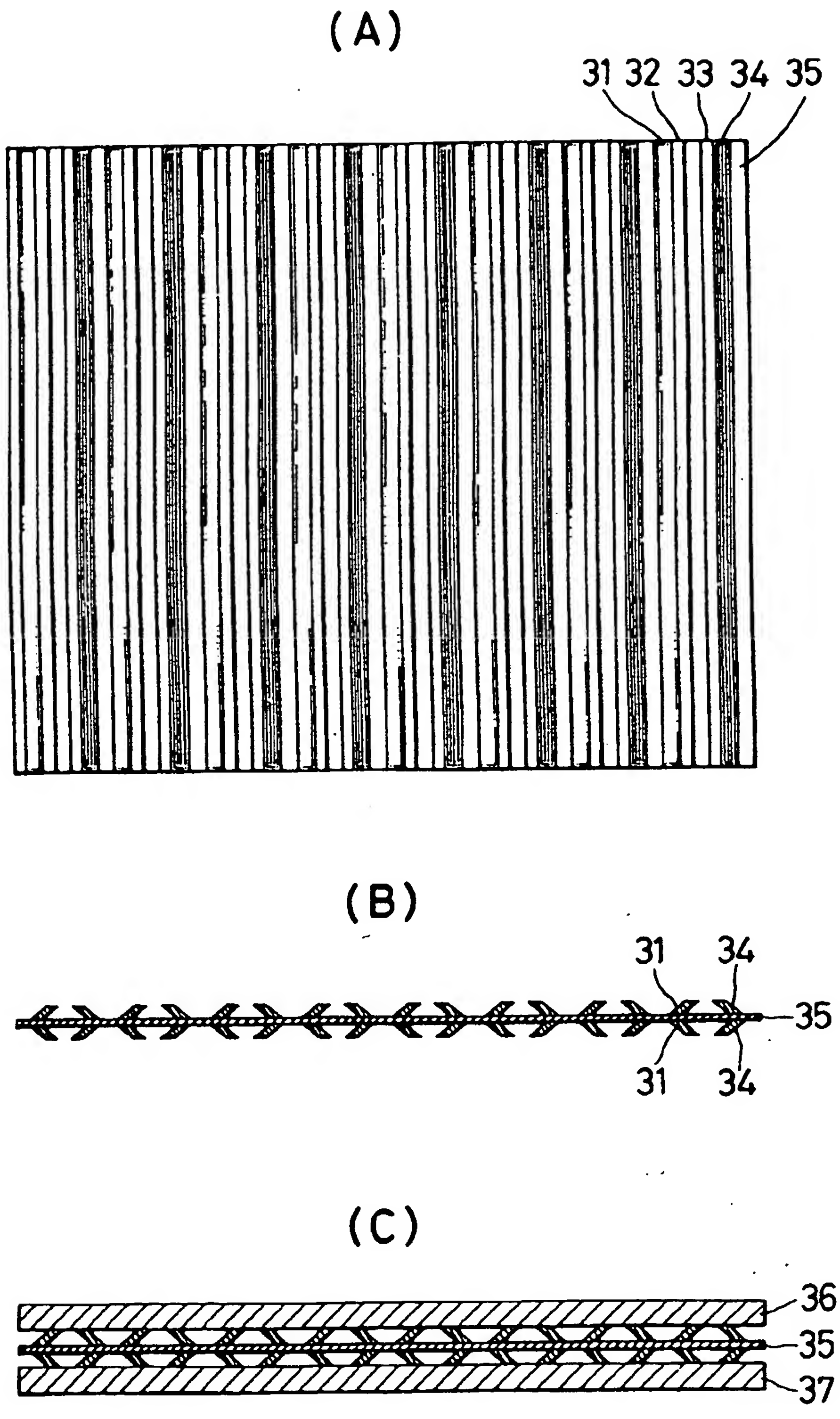


Fig 31

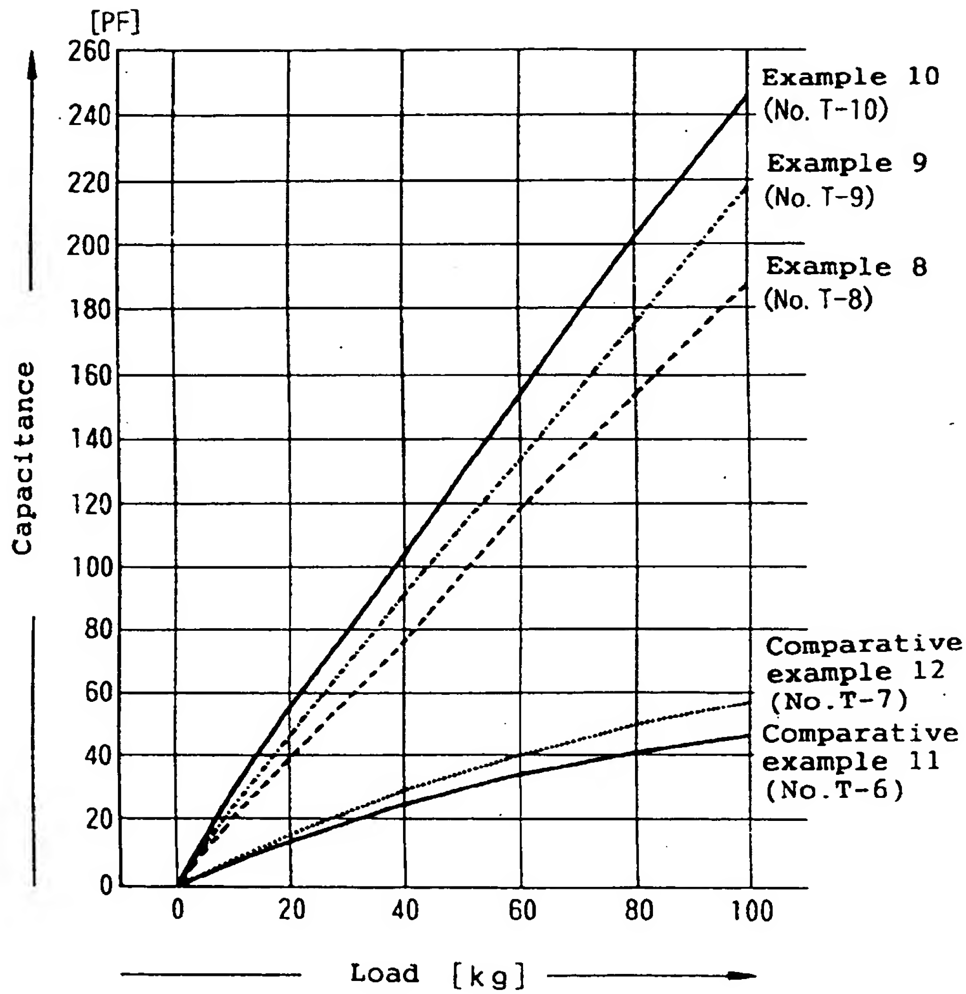

[PF]
260
240
220
200
180
160
140
120
100
80
60
40
20
0
Capacitance
0
20
40
60
80
100
Load [kg]
Example 10
(No. T-10)
Example 9
(No. T-9)
Example 8
(No. T-8)
Comparative
example 12
(No.T-7)
Comparative
example 11
(No.T-6)

Fig 32

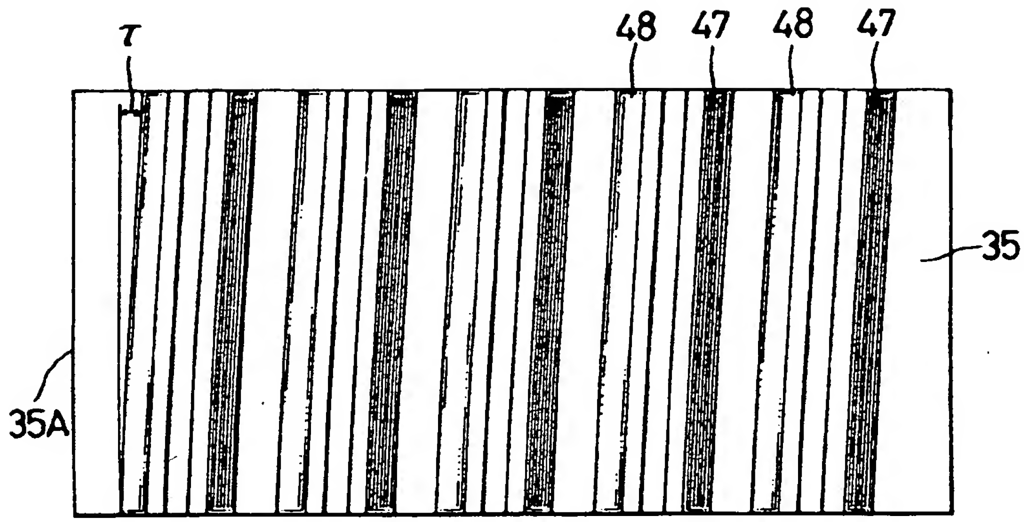


Fig 33

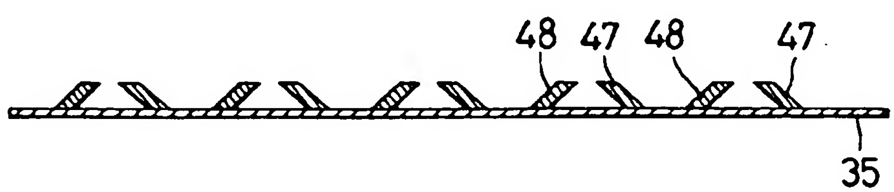


Fig 34

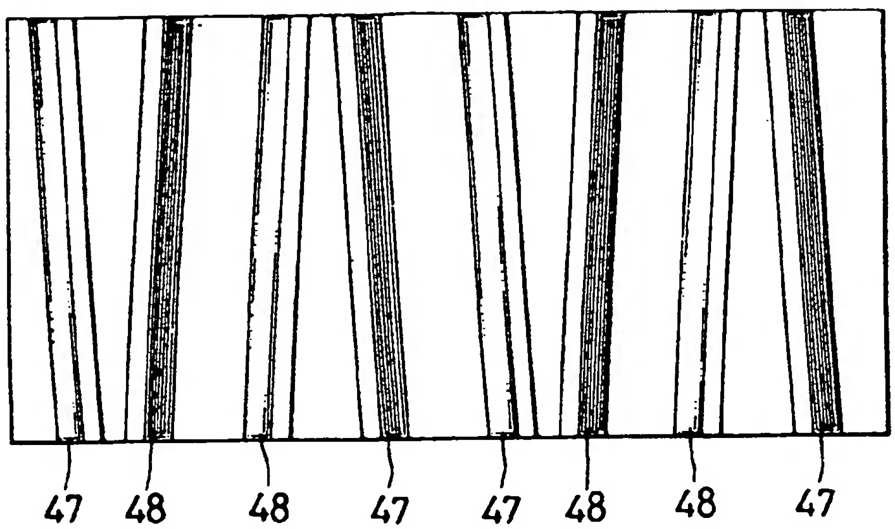


Fig 35

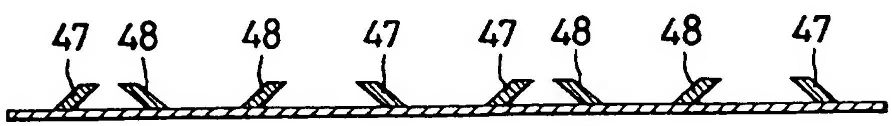


Fig 36

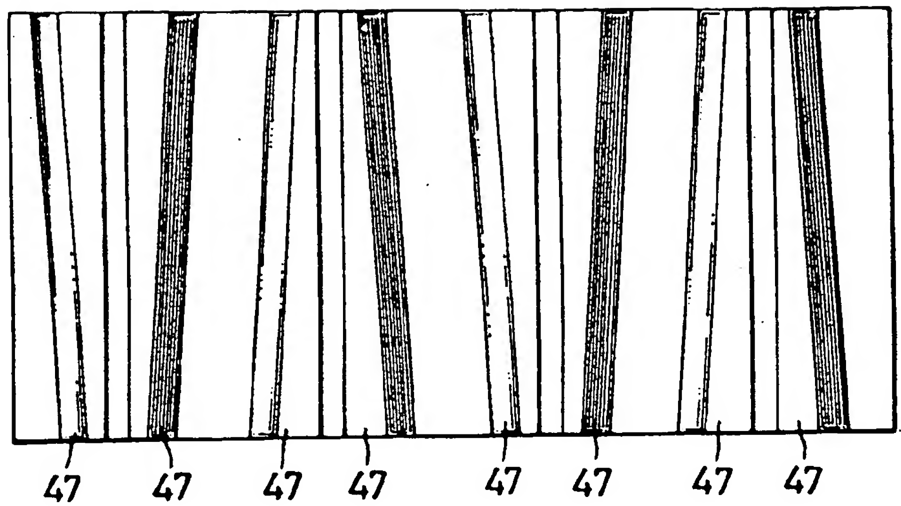


Fig 37

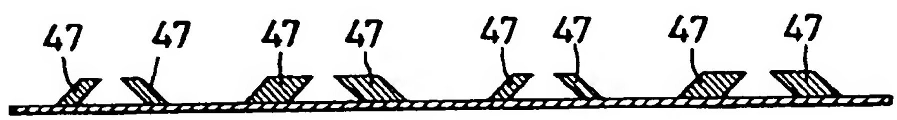


Fig 38

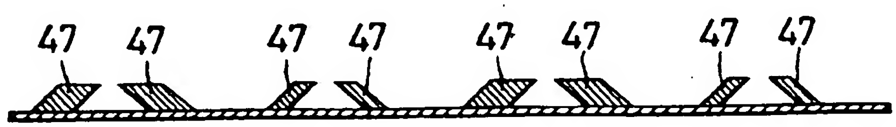


Fig 39

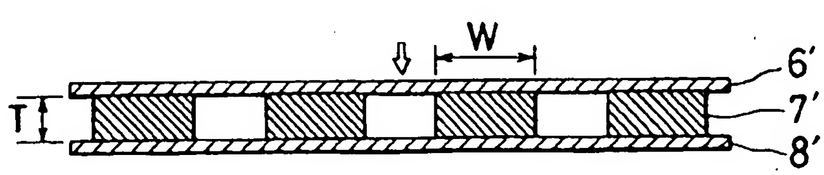


Fig 40